SERDP
Strategic Environmental Research and Development Program

ANNUAL REPORT TO CONGRESS—FISCAL YEAR 2001

FROM THE STRATEGIC ENVIRONMENTAL RESEARCH AND DEVELOPMENT PROGRAM

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EXECUTIVE SUMMARY

The Strategic Environmental Research and Development Program (SERDP) is the Department of Defense's corporate environmental science and technology program. To fulfill its mission to address environmental problems through innovative research and share that information across Federal and private organizations, SERDP executes the program in partnership with the Department of Energy and the Environmental Protection Agency. Further, SERDP fully leverages complementary programs within the Department of Defense and solicits interest from other public and private research organizations.

The organization and management of SERDP is described in Section I. As directed by the SERDP Council, the Executive Director and Program Office Staff implement the Program with the support of various working groups and panels to meet high priority, DoD mission-related environmental needs. The activities, achievements, and recommendations of the SERDP Council, Scientific Advisory Board, and Executive Director are detailed in this section.

SERDP conducts basic research through advanced technology development in the following five Technology Thrust Areas: Cleanup, Compliance, Conservation, Pollution Prevention, and Unexploded Ordnance (UXO). Section II describes significant accomplishments achieved during FY 2001 within each of the Thrust Areas. Highlights of these accomplishments include: (1) new technologies capable of detecting UXO with high detection rates to significantly reduce the cost of DoD site characterization and cleanup; (2) new technologies to remediate and/or contain groundwater contaminated with explosives and ammonium perchlorate; (3) advances to achieve the long-term sustainability of DoD testing and training ranges, including adaptive management of ecosystems and techniques to assess the potential release of energetics pollutants; and (4) new technologies for economically-feasible, environmentally-acceptable, and user-safe techniques and fluids for fire suppression. Each of these advancements will ensure DoD maintains mission-readiness while complying with high priority and emerging environmental requirements.

In each fiscal year cycle, SERDP must manage ongoing research within the program, solicit and select new research projects, and plan future research initiatives and funding distribution for each Thrust Area. Section III provides an overview of the SERDP Program, including the goals, environmental and operational research drivers, actual and planned funding levels, and the planned research initiatives for the Program. In FY 2001, the SERDP budget was $59.01 million for the funding and management of 126 research projects. The FY 2002 appropriation of $62.17 million will be used for at least 131 projects, including both continuing and new start projects. Summaries of each project funded in FY 2001 and those planned for funding in FY 2002 are provided for the five Thrust Areas in Appendices A through E. Research topic areas for which proposals will be requested for projects funded in FY 2003 are provided in Appendix F.

This report provides a summary of SERDP's activities and its most significant accomplishments for FY 2001, its plans for FY 2002, and new research activities to be addressed in FY 2003. It responds directly to the requirements as stated in Title 10, U.S.C. section 2902, as modified. This report complies with FY 2001 amendment to the SERDP statute that repeals the requirement for an Annual Report from the SERDP Scientific Advisory Board, and includes the contents of that report in this Annual Report to Congress.

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I. PROGRAM MANAGEMENT

Background

Authorizing Legislation

In June of 1990, Senator Sam Nunn addressed the Senate to advise his colleagues about the seriousness of the environmental problems faced by this nation, and specifically by the Department of Defense (DoD) and the Department of Energy (DOE). Having recently been relieved of the strenuous efforts and financial burden of the Cold War, it became apparent to Senator Nunn and others that a significant capability existed both in the nation's Federal research infrastructure, as well as the defense industry, whose technical skills could be brought to bear on this Nation's environmental matters of concern. From this revelation, he recommended the creation of a Strategic Environmental Research Program, composed of several Agencies and Departments, that would seek to apply defense technologies for environmental benefits.

Later that year, Public Law 101-510 (Title 10, U.S.C., §§2901-2904) established the Strategic Environmental Research and Development Program (SERDP) funded by DoD and planned and executed in partnership with DOE and the Environmental Protection Agency (EPA). The immediate success of the Program led to SERDP becoming the DoD's corporate environmental Science and Technology (S&T) program. SERDP fully leverages complementary programs found within the Army, Navy, and Air Force, and those of the DOE and the EPA. Over the past decade, measures have been implemented to take full advantage of the intrinsic capabilities of the participating organizations. This feature makes SERDP unique, as it can tap the vast technical resources of the Federal research infrastructure to meet the needs of our most pressing environmental matters of concern. During the past six years, SERDP has successfully engaged in directly funding the private sector and academia in a step that further widens the spectrum of technological capability and innovation.

This report provides a summary of SERDP's activities and most significant accomplishments during fiscal year 2001, its plans for fiscal year 2002, and new research initiatives to be addressed in fiscal year 2003. It responds directly to the reporting requirements as stated in Title 10, U.S.C. §2902. This report also complies with the amendment to the SERDP statute that repeals the requirement for an Annual Report from the Scientific Advisory Board (SAB), but includes the actions of the Board in the Annual Report of the SERDP Council to Congress.

Mission

The purposes or mission of SERDP can be found in the statute and are paraphrased below. The clear intent of Congress was to not only address environmental problems through research efforts, but also to share information across and within Federal and private lines in order to more rapidly and effectively deal with these serious problems. Specifically, the four purposes of SERDP are to:

SERDP addresses DoD and congruent DOE environmental matters of concern through cooperative research.

- Address environmental matters of concern to the DoD and the DOE through support for basic and applied research and development of technologies that can enhance the capabilities of the Departments to meet their environmental obligations;
- Identify research, technologies, and other information developed by the DoD and the DOE for national defense purposes that would be useful to governmental and private organizations involved in the development of energy technologies and of technologies to address environmental restoration, waste minimization, hazardous

waste substitution, and other environmental concerns and to share such research, technologies, and other information with such governmental and private organizations;

- Furnish other governmental organizations and private organizations with data, enhanced data collection capabilities, and enhanced analytical capabilities for use by such organizations in the conduct of environmental research; and

- Identify technologies developed by the private sector that are useful for DoD and DOE defense activities concerning environmental restoration, hazardous and solid waste minimization and prevention, and hazardous material substitution and provide for the use of such technologies in the conduct of such activities.

This mission, crafted over 10 years ago, remains highly relevant, and while significant successes have been achieved, a number of difficult technical challenges remain.

Requirements

SERDP is a "requirements-driven" program that directly responds to defense requirements generated by the Services and sanctioned by the Deputy Under Secretary of Defense for Installations and the Environment (DUSD/I&E). It is critical that the limited funds available for environmental technology R&D be focused on the highest priority requirements of the Services. Each Service develops prioritized user requirements through internal processes that include members of the technology user community. These requirements are collected, cross-referenced, and correlated at the DoD level by the DUSD(I&E) through the Environmental Security Technology Requirements Group (ESTRG). The ESTRG is composed of the officials responsible for the Environmental Security programs within the Services and representatives of the R&D community.

Requirements submitted to the ESTRG are validated and ranked into high, medium, and low categories based on the priorities assigned by the Services. They form the basis of the Defense Technology Objectives (DTO) for environmental technology programs of the Services, SERDP, and the Environmental Security Technology Certification Program (ESTCP). The environmental technology DTOs are merged with other DTOs for other defense technology requirements within the DoD to form the overarching Defense Technology Area Plan (DTAP). The DTOs and the DTAP are developed jointly by the Services and DDR&E through the Reliance Process and form the basis for all DoD Science and Technology initiatives.

DoD environmental concerns may be divided into two broad categories of concerns:

- Those that impact training, logistics, and combat operations, and
- Those that have cost and performance impacts on the supporting infrastructure.

Both categories can negatively impact the Department's ability to perform its primary mission of maintaining military readiness for national defense.

In the course of addressing DoD's highest priority environmental needs in the areas of Cleanup, Compliance, Conservation, Pollution Prevention, SERDP, and Unexploded Ordnance (UXO). SERDP also has sought opportunities to help solve other significant national and international environmental problems through the application of DoD's technical capabilities, analytical systems, and information.

The SERDP Management Structure

SERDP is a multi-agency managed program funded by the Department of Defense. Pursuant to Title 10, U.S.C., SERDP receives general oversight and policy guidance from the SERDP Council which is composed of members from the DoD, DOE, and EPA. Also included in this authorizing language is a requirement for an Executive Director to lead the day-to-day Program activities, and a Scientific Advisory Board (SAB) that is charged with providing advice and recommendations to the SERDP Council on projects/proposals reviewed. Further, the SAB may advise the Council regarding other programmatic, funding, or technically related issues with respect to the Program. Other activities shown in Figure I-1 represent those that were established by the Council and Executive Director to support Program needs.

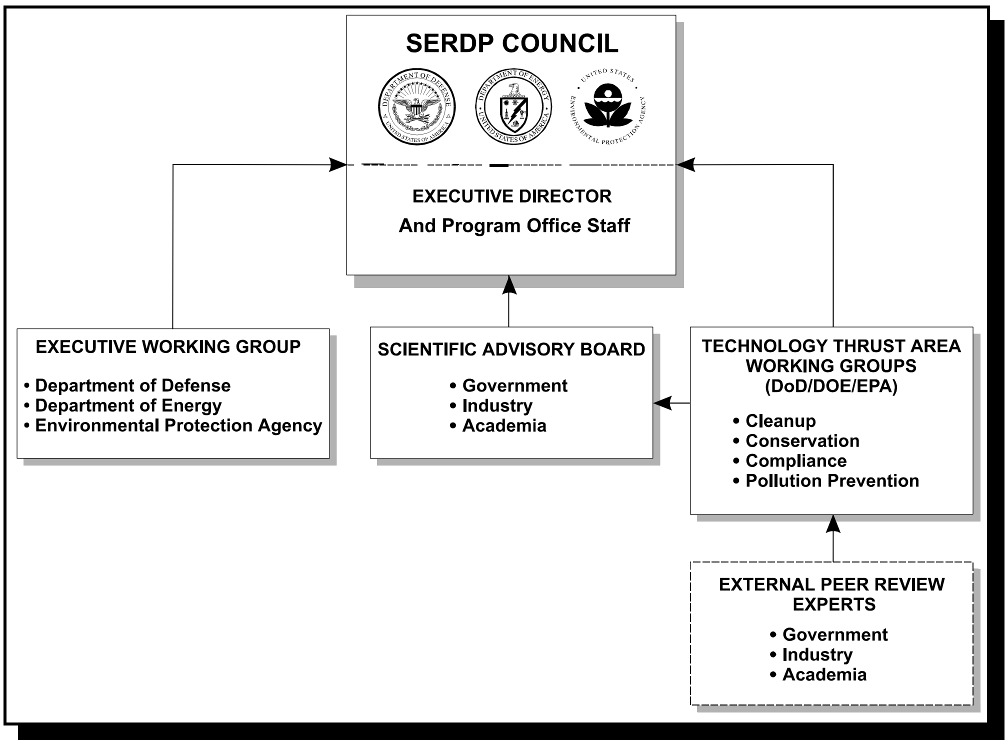

Figure I-1. SERDP Organization.

SERDP Council

Title 10, U.S.C. §2902 established the Strategic Environmental Research and Development Program Council to oversee management of SERDP. Specifically, this Council prescribes policies and procedures to implement the Program and, uniquely, is the sole funding approval authority. As such, the Council may enter into contracts, grants, and other agreements in accordance with other applicable law to carry out the purposes of SERDP. Congress intended the Council to be a multi-agency membership body to promote maximum exchange of information and to minimize duplication of environmentally related research, development, and demonstration activities through close coordination with the military departments and Defense agencies; the Department of Energy; the Environmental Protection Agency; the National Oceanic and Atmospheric Administration; the National Aeronautics and Space Administration; other departments and agencies of the Federal, State, and local governments; and other organizations engaged in environmentally related research.

Established by law, SERDP's multi-agency Council ensures integrated, non-duplicative research.

DoD and DOE Council representatives alternate as Chair.

Consistent with the SERDP statute and with facilitating multi-agency cooperation, the Secretary of Defense has designated the Director, Defense Research and Engineering (DDR&E) as chairperson for each odd-numbered fiscal year, and the Secretary of Energy has designated the Director of the Office of Science to serve as chair for each even-numbered year. Other members are assigned per guidance provided in the SERDP statute. The following are the Council members who served during a portion of, or for the entire, FY 2001.

Council Members - FY 2001

Dr. Ronald Sega
Department of Defense
Defense Research and Engineering

Dr. James Decker
Department of Energy
Office of Science

Colonel Brian McCarty
Department of the Air Force
Environment, Safety, and Occupational Health Technologies

Ms. Kathleen Carlson
Department of Energy
Defense Programs

Mr. Ray DuBois
Department of Defense
Installations & Environment

Captain Jim Evans
U.S. Coast Guard
Research and Development

Ms. Jessie H. Roberson
Department of Energy
Environmental Management

Ms. Catherine Kominos
and Dr. Thomas Killion
Department of the Army
Research and Laboratory Management

Mr. Henry L. Longest (II, P.E.)
Environmental Protection Agency
Research and Development

General Richard Myers
Department of Defense
Joint Chiefs of Staff

Dr. Fred Saalfeld
Department of the Navy
Naval Research

Mr. Bradley Smith *(non-voting member)*
Executive Director
Strategic Environmental Research and Development Program

Executive Working Group

The Executive Working Group (EWG) is an extension of the Council and serves as a working-level representation of the Council. This body, while not established by law, facilitates SERDP policy preparation, investment strategy considerations, and annual program plan development.

SERDP Scientific Advisory Board

SAB members focus on technical quality.

Established in accordance with the SERDP statute, the SERDP Scientific Advisory Board (SAB) assures that the Program maintains clear focus on technical quality. The SAB has the authority to make recommendations to the Council regarding technologies, research, projects, programs, activities, and, if appropriate, funding within the scope of the SERDP. The SAB is composed of no more than 14 members who are jointly appointed by the Secretary of Defense and the Secretary of Energy in consultation with the Administrator of the Environmental Protection Agency. During FY 2001, SAB membership remained consistent.

To ensure that SERDP objectives are congruent with the Administration's goals, two members of the SAB are mandated in the statute - the Science Advisor to the President, or his/her designee, and the Administrator of the National Oceanic and Atmospheric Administration, or his/her designee. Similarly, to ensure that regional and global environmental issues are appropriately addressed in SERDP, at least one member should represent the interests of State governments and one member should represent environmental public interest groups. The list below reflects SAB membership in FY 2001.

Scientific Advisory Board Members - FY 2001

Dr. Braden Allenby
AT&T

Dr. Patrick R. Atkins
Aluminum Company of America

Dr. Mary Barber
The Ecological Society of America

Dr. Rosina M. Bierbaum
Office of the Science Advisor to the President

Dr. Steven Clifford
National Oceanic and Atmospheric Administration

Dr. Ronald Heck
Cummins, Inc.

Dr. Carol Henry
American Chemistry Council

Dr. Michael Kavanaugh
Malcolm Pirnie, Inc.

Dr. Perry L. McCarty
Stanford University

Dr. Jean'ne M. Shreeve (Vice Chair)
University of Idaho

Dr. C. Herb Ward (Chair)
Rice University

Mr. Randolph Wood
Texas Natural Resources Conservation Commission

Dr. Lily Young
Rutgers University

The statute directs the SAB to review all projects with a value in excess of $1,000,000. Several years ago, the SERDP Council modified this direction by requesting that each new start effort and every continuing project exceeding $900,000 be reviewed by the SAB. During FY 2001, each project meeting this criteria was reviewed to ensure technical quality and fiscal responsibility. Furthermore, the SAB confirmed that multiple projects responding to the same or a similar requirement were complementary in approach and well coordinated.

Executive Director and Program Office Staff

Title 10, U.S.C. authorizes an Executive Director to direct and focus the day-to-day efforts of SERDP, and Mr. Bradley P. Smith retained the position of Executive Director. The Executive Director is a non-voting member of the SERDP Council and a voting member of the EWG. Dr. Jeffrey Marqusee, the Environmental Security Technology Certification Program (ESTCP) Director, also served as the SERDP Technical Director. Collocation of SERDP and ESTCP has served to broaden the staff's technical skills and facilitate technology transition from one program to another. The balance of the Federal staff consisted of four technical Program Managers and a Financial Officer who have been detailed from the military Services' R&D infrastructure. These individuals include:

- Dr. Anne Andrews - Program Manager for UXO technologies
- Ms. Catherine Vogel - Program Manager for Cleanup technologies (through August, 2001)
- Dr. Andrea Leeson - Program Manager for Cleanup technologies (after August, 2001)
- Mr. Charles Pellerin - Program Manager for Pollution Prevention technologies
- Dr. Robert Holst - Program Manager for Compliance and Conservation technologies
- Ms. Brenda Batch - Financial Officer

Technology Thrust Area Working Groups

As evidenced by the small size of Program Office staff, the breadth of technical knowledge demanded by SERDP far exceeds the limited staff in the SERDP Program Office. Consequently, SERDP must rely on the technical skills offered by the participating Services and Agencies to assist in the technical aspects of program development, program monitoring, and technology transfer. For each of the Technology Thrust Areas, a Technology Thrust Area Working Group (TTAWG) was established to help solicit and review technical proposals, formulate and recommend the annual program plan, conduct technical reviews of the ongoing projects, and facilitate technology transfer according to the needs of their users in the field. TTAWGs offer several advantages over conventional R&D management schemes. First, their members are selected by the Services and Agencies as represented on the Council. Second, they bring not only a wealth of understanding of the needs of their organization, but also knowledge of similar completed or ongoing efforts. This knowledge helps SERDP to avoid duplication of effort and promote joint and cooperative funding of projects. TTAWG members, for the most part, are provided from their services as a collateral assignment, however, without their assistance, SERDP would have difficulty achieving the same level of success.

Peer Review Experts

SERDP supports an electronic peer evaluation process via the Internet.

Assisting the TTAWGs and the Program Office in their quest to select quality research proposals are the Peer Review Experts. Following the model established by the National Science Foundation, SERDP proposals must undergo an independent Peer Review prior to receipt of initial funding. The results, scores, and evaluation comments of this review are passed directly to the TTAWGs who use this information to develop their recommended list of new start projects. Further, these same results are passed to the Scientific Advisory Board for consideration during their proposal review and deliberations.

Peer Reviewers come from all walks of disciplinary life - from industry, academia, and government as well. Each reviewer is certified to be without conflict of interest, an expert in their field and profession, and credible on record. Peer Reviewers are identified and tasked under a support contract, and in FY 2001, 91 Peer Review Experts were used to evaluate 190 proposals.

SERDP Strategy

Program Goals

The SERDP Council ensures that the partnership focuses on the mission needs of the DoD and empowers the EWG with developing goals and an investment strategy that will assist SERDP to successfully satisfy these mission needs. In 1993, the EWG assembled to develop the SERDP Strategic Guidance that served as a framework within which to develop the annual SERDP program plan. This Strategic Guidance continues to provide the overarching guidelines to Program Managers and participants in the Program. Included in this document are the SERDP goals which are to:

- Resolve environmental concerns in ways that enhance military operations, improve military systems effectiveness, and help ensure the safety of personnel; and
- Support technology and process development that reduce operational and life cycle costs, including those associated with environmental cleanup and costs of full compliance with environmental laws and regulations.

SERDP achieves its goals by promoting cooperative environmental technology development and a strong effort in information dissemination. Specifically, SERDP succeeds by:

- Identifying and supporting programs of basic and applied research and development to:
  - Accelerate cost-effective cleanup of contaminated defense sites.
  - Facilitate full compliance with environmental laws and regulations at reduced cost.
  - Enhance training, testing, and operational readiness through prudent land management and conservation measures.
  - Reduce or eliminate defense industrial and operational waste streams through aggressive pollution prevention programs that strongly encourage use of non-hazardous, non-toxic, non-polluting, and other environmentally sound materials, substances, and processes.
- Promoting the effective exchange of information regarding environmentally related research and development activities.

SERDP promotes cooperative environmental technology development and information transfer.

- Ensuring that SERDP research and development (R&D) activities complement, but do not duplicate, Tri-Service R&D programs and other ongoing activities.
- Providing appropriate access to data under the control of, or otherwise available to, the Departments of Defense and Energy that is relevant to environmental matters.
- Facilitating the transfer of unclassified DoD and DOE environmental information and technology to other sectors of society that might be able to use them to advance national environmental objectives.
- Emphasizing multi-service, inter-departmental research and development projects and using the unique capabilities of the partnering Federal agencies, private industry, and academia to solve the Departments' environmental problems.

Key Metrics for SERDP Success

The following four key metrics are used to maintain Program quality and enhance the success of the Program:

1. Address the highest-priority, defense mission-relevant environmental requirements with emphasis on multi-service issues.

The Executive Director and his staff worked hand-in-hand with ODUSD(I&E) to establish clear lines of communication, address effectively the Department's highest priority environmental requirements, and foster transition of technical efforts to field demonstration or implementation. Through the use of focused Statements of Need, the Executive Director solicited cooperatively funded and executed projects to address high-priority multi-service needs. The TTAWGs facilitated this process by communicating effectively and applying their knowledge of the needs and capabilities of the Federal R&D infrastructure.

SERDP often holds workshops to explore the state-of-science, technology gaps, and opportunities for research in needs area as where it may be difficult to interpret this need. From these workshops, several key Statements of Need can be identified. In FY 2001, three workshops were held, one on Military Depot Environmental Requirements, one on Regional Ecosystem Management Approaches, and one on Chlorinated Solvents.

2. Pursue/achieve universal, world-class technical excellence.

World-class research is considered the cornerstone of SERDP projects. Continuing the successful solicitations of the past few years, SERDP solicited proposals from all sources including the non-Federal sector. SERDP continued to use external Peer Review Experts in addition to the comprehensive multi-agency review procedures to ensure that technically sound proposals performed by world-class researchers are selected for funding. Technical experts representing universities, industry, and government participate in the Peer Review process. Additionally, the SAB, TTAWGs, and the Program Office staff all emphasize the need for each research team to demonstrate superior technical merit and perform according to world-class research standards.

3. Emphasize and promote technology transfer.

Transfer of technology, from research to the DoD environmental user community, is one of the key objectives of SERDP. This objective is achieved by supporting applied research and technology demonstrations that respond directly to high-priority, DoD mission-related, environmental needs. With FY 2001 marking its tenth year of technology development, SERDP is aggressively pursuing technology transfer mechanisms. The recent co-location of ESTCP with SERDP has already helped to facilitate project transitions, both between Programs and into other Agencies' certification programs as well. Many of the projects initiated in the earlier years have been, or are being completed and are now ready for field demonstration, implementation, or transition to the next step of development.

Significant focus on technology transfer has been placed on the Principal Investigators (PI) of all SERDP projects at both briefings to the SAB as well as at the In-Progress Reviews (IPR). At these IPRs, PIs are required to demonstrate their interaction with the user community or those who will sponsor further development. Members of the multi-agency TTAWGs, Joint Engineers Management Panel (JEMP) members, and key representatives from ODUSD(I&E) attended the IPRs in FY2001 and provided various potential technology transfer opportunities to the PIs.

4. Ensure sound fiscal management.

Timely and complete financial reporting is one of the principal keys to SERDP's success. The SERDP Executive Director has continued to ensure that the Program complies with the DoD fiscal guidance. Effective controls include periodic fiscal review of projects, implementing aggressive corrective actions to promote effective use of limited R&D resources, and implementation of various information management/monitoring tools which fully utilize state-of-the-art Internet capabilities.

Research Framework and Technical Strategy

SERDP has the flexibility to fund basic and applied research, or advanced technology development projects as needed.

Within the Services' Environmental Quality Programs, Program Elements exist to provide funding specifically focused on either basic research, applied research, or advanced technology development. The authors of SERDP's statute understood the need to easily and judiciously allocate funds against the highest priorities and most intractable problems faced by DoD. Accordingly, SERDP has the flexibility to perform under all of these research categories. Figure I-2 illustrates SERDP's role in the DoD environmental technology development process.

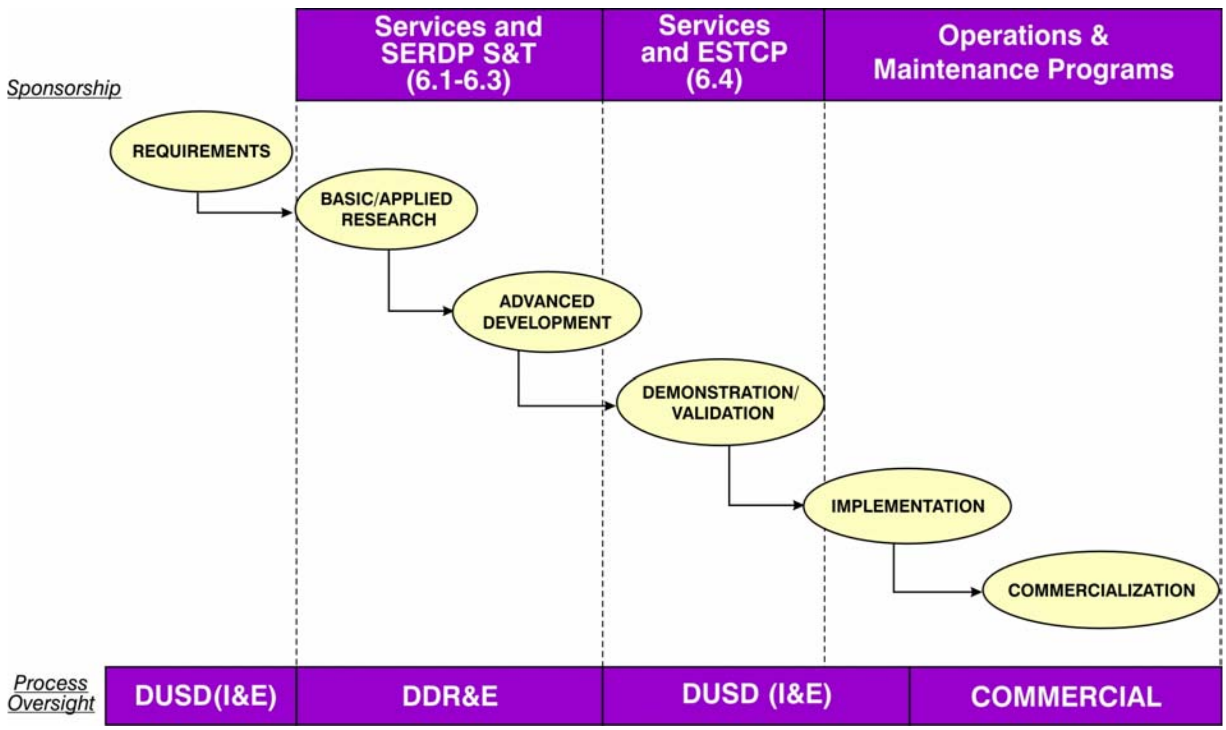

Figure I-2. Environmental Technology Development Process.

Figure I-3 represents the research taxonomy that defines the SERDP Program. The primary areas of emphasis were developed in response to user community needs for science and technology required to accomplish the military mission in an environmentally compliant manner. This taxonomy follows the four pillar structure that is consistent with the focus of the Office of the Deputy Under Secretary of Defense for Environment and Installations [ODUSD(I&E)], that corresponds to those identified in the National Environmental Technology Strategy. The research taxonomy reflects the current areas of emphasis under each of the four pillars, plus an added fifth pillar that reflects the recent increases in funding and need for research in unexploded ordnance (UXO) technologies.

CLEANUP	COMPLIANCE	CONSERVATION	POLLUTION PREVENTION	UNEXPLODED ORDNANCE
Site Characterization and Monitoring	Air Emissions Monitoring and Control	Ecosystems Restoration and Mitigation	Air Emissions	Site Characterization and Sensor/Platform Development
Remediation	Marine Environmental Issues	Threatened and Endangered Species	Elimination of Chromium/Cadmium	Data Processing/ Fusion for Discrimination
Risk Assessment Technologies	Energetic Materials in the Environment	Ecosystem Processes	Green Energetics	Tools for Removal and Disposal of UXO
	Solid Waste and Wastewater Treatment	Cultural Resource Management	Next Generation Fire Suppression	
	Noise	Ecological Forecasting	Hazardous Materials and Solid Waste Reduction	

Figure I-3. SERDP Research Taxonomy.

Technical Strategy

For FY 2001, the SERDP Council directed the continuing pursuit of seven avenues in planning and executing defense mission-relevant environmental research and development:

- ✔ Identify and fund major-impact, multi-agency environmental R&D programs to solve high-priority, mission readiness related concerns of DoD;
- ✔ Identify opportunities to accelerate existing DoD environmental quality R&D programs and fund those that address the highest priority concerns of the Department;
- ✔ Advance and use applicable state-of-the-art modeling and simulation capabilities to accomplish SERDP goals;
- ✔ Use the technical and research capabilities of the SERDP partners, including their unique data collection and analysis capabilities, as appropriate;
- ✔ Plan for a transition of successfully proven technologies to demonstration and validation or to commercialization and implementation; and
- ✔ Encourage high-risk, high-payoff novel approaches to resolve environmental problems through the use of low-cost, short-term, exploratory R&D efforts.

Search for Innovation

With respect to the last strategic element, SERDP continues to seek innovative ideas with commensurate technical risk. The SERDP Exploratory Development Program, or SEED, that was initiated in FY 1999, has succeeded in soliciting novel ideas that were demonstrated under a low-cost ($100,000 or less), short-term (one year), proof-of-concept study. SEED projects and the larger, longer-term "Core" efforts both respond to the highest priority needs as defined in published Statements of Need (SON). These SONs are released annually with a Federal Call for Proposals and a non-Federal Broad Agency Announcement. In search of world-class research, SERDP promotes direct participation from the private sector, including small and large businesses and academic institutions. In FY 2001, three of these SEED efforts (two in Compliance and one in Pollution Prevention) were successful in their study phase and are proposing follow-on work for FY 2002. The accomplishments of these efforts are described in Section III entitled, "Program Description" and Appendices A and E.

Investment Strategy

Each year the SERDP Council annually determines the distribution of funding to the Thrust Areas. The Council seeks the advice and recommendations of the SERDP Scientific Advisory Board and the Executive Working Group to best position SERDP to respond to both pressing needs as well as environmental problems that loom in the future. For FY 2001, the Council had approved maintaining the allocation of resources among the pillars at their FY 2000 levels. Prior year strategies had called for the continued reduction in the Cleanup thrust area. The Council recognized that the investment in Cleanup could not continue to decline due to the continued intractability of the remediation of chlorinated solvents and the emergence of the UXO issue.

In FY 2002, there will be a major shift in the investment allocation among the thrust areas. In recognition of the growing impact that environmental issues are having on training and testing ranges as well as the enormity of the future liability for the remediation of lands contaminated with UXO, the Amended President's Budget Request increased the funds requested for SERDP by $20 million. These funds were directed by the issues of UXO remediation and environmental issues impacting training and testing ranges. Of this $20 million increase, Congress appropriated only $10 million.

Management Actions

Council

Multi-agency management and oversight of SERDP continues to be one of the clear strengths of SERDP. Active participation by the members of the SERDP Council, their designated representatives on the Executive Working Group (EWG), and participation on the Technology Thrust Area Working Groups (TTAWG) precludes duplication of effort, ensures quality Program content, and facilitates information transfer. This tri-parte arrangement, composed of executive, programmatic and technical individuals who represent the three primary participating organizations, yields a depth and breadth of knowledge and experience at several levels of management and technical expertise lending significant credibility to the Program.

Multi-Agency participation is a clear strength of the Program.

On September 28, 2000, the SERDP Council approved the FY 2001 Program Plan and the FY 2002 Investment Plan. For FY 2001, SERDP was appropriated $59.5 million that included funding for several additional congressional interest projects.

The Council met one year later on September 26, 2001 to approve the FY 2002 Program. The Amended President's Budget Request for FY 2002 included an increase of $20 million for SERDP. This increase was to address development of technologies for the remediation of UXO and to address environmental issues impacting the training and testing ranges. As the Amended President's Budget Request was not forwarded to Congress until July of 2001, a Supplemental Solicitation was developed and released in August to solicit projects for the additional funds. The Council approved the FY 2002 core program as presented. They also approved the statements of need for the Supplemental Solicitation and granted the Executive Director the authority to administer the Supplemental Solicitation without further approval by the Council. The Council further granted the Executive Director the authority to execute any Congressional interest projects that may be added to the appropriation. The Council reviewed and approved the FY 2003 new start areas.

Scientific Advisory Board

In accordance with Section 2904, Title 10, U.S.C., the Scientific Advisory Board (SAB) is required to meet a minimum of four times during the Fiscal Year. In FY 2001, the SAB met five times. One meeting was held in Coeur D'Alene, ID, and three meetings were held in Arlington, VA. A fifth meeting held in Falmouth, MA was adjourned early on September 11 due to the terrorist attacks in Washington, DC, New York City, and Pennsylvania. Consistent with the statute, the Board made recommendations to the SERDP Council through the Executive Director regarding the projects reviewed. They also assisted and advised the Council in identifying environmental opportunities and provided advice on other environmental issues within the scope of SERDP.

Figure I-4 provides a list of dates and locations of all SAB meetings held during FY 2001. In accordance with the Federal Advisory Committee Act, all meetings were open to the public and detailed records of events are maintained. Further, all records, reports, working papers, and agendas were made available to the public for review. In FY 2001, no requests were made to review this information.

SAB Meeting No.	Dates	Location	Projects Briefed		
			Ongoing	New Starts	Total
1	October 16-17, 2000	Coeur D'Alene Resort Coeur D'Alene, ID	7	6	13
2	March 27-28, 2001	National Rural Electric Cooperative Association Arlington, VA	3	11	14
3	June 13, 2001	National Rural Electric Cooperative Association Arlington, VA	3	3	6
4	August 8-9, 2001	National Rural Electric Cooperative Association Arlington, VA	-	14	14
5	September 11-12, 2001	Holiday Inn Cape Cod Falmouth, MA	-	6	6

Figure I-4. Summary of FY 2001 SAB Meetings.

During FY 2001, the SAB continued to be committed to enhancing three processes within SERDP: research initiation, quality control, and technology transfer.

Commitment to Enhancing the Research Initiation Process

Consistent with the SAB's desire to define and fulfill its role within SERDP's statutory requirements, in a manner that most effectively utilizes the collective expertise and experience of the Board, the SAB reaffirmed its commitment to ensure that SERDP complies with the statute by soliciting and funding projects that are sharply focused on the environmental needs of the DoD and those congruent needs of the DOE. The Board reviewed and contributed to the process of preparing and issuing Statements of Need (SON). In the course of review, the SAB was instrumental in identifying opportunities to enhance the expected research product. Additionally, their final quality control review ensured that the SONs clearly articulated the objective of each and every need. This process was instrumental to fostering properly focused research proposals and minimizing irrelevant submissions in response to the broad solicitation.

The Board continued its proactive strategic role in identifying and defining environmental research gaps and associated technology development opportunities. The Board continued to support strongly the concept of focused technical workshops to provide an assessment of the state of the science and identify and prioritize research needs specific in areas of interest to SERDP. As a result of workshops held in the past, numerous SONs were generated that resulted in many proposals. For example, the ongoing FY 2003 solicitation includes three SONs related to chlorinated solvents issues including: DNAPL Source Zone Delineation and Characterization, Diagnostic Procedures to Evaluate Remediation Performance at Chlorinated Solvent-Contaminated Sites, and Assessment of Long-Term Sustainability of Monitored Natural Attenuation of Chlorinated Solvents. These SONs directly correspond to research needs articulated in a workshop held on Chlorinated Solvents in FY 2001.

During their review and evaluation of proposals, the SAB conscientiously scrutinized each effort to understand and enhance the research partnerships that were proposed. Considered to be a major strength of the Program, cooperative research efforts have demonstrated a higher quality of effort by ensuring that each facet of the project is afforded a second look and chance to ensure that it is conducted with the highest standards. Where appropriate, the SAB suggested improvements or additions to the research team - from inclusion of a Co-PI having specific disciplinarian credentials that would enhance the research effort, to offering suggestions of organizations that might shed additional light and enhance the standards and procedures proposed in the effort. The SAB also strongly encouraged inclusion of graduate students in research teams to promote training and foster development of technical expertise in cutting edge technologies.

Commitment to Ensuring Quality Research

The Board continued its key focus on assisting SERDP to ensure that SERDP-supported projects meet the highest standard of technical and scientific quality. The SAB addressed this issue from three avenues.

- First, the members strongly endorsed the established proposal review process. The SAB firmly supports SERDP's procedure to have each and every proposal reviewed by at least three Peer Reviewers that are experts in the discipline most closely related to the proposal's technical approach. All Peer Review comments are forwarded to the SAB prior to their meetings and are used extensively by the members during proposal discussions with the Principal Investigator. These review comments complement the Board members' already diverse and deep technical expertise.

- Second, the members encouraged close coordination between projects that address related problems. In this sense, the Board evaluated projects on more than just the basis of their individual scientific merit and DoD relevance, putting increasing emphasis on coordination and leveraging between projects to ensure that related efforts indeed complement each other. As demonstration of this emphasis, the Board voiced its support for the use of a Technical Advisory Committee for "umbrella"-type projects, i.e., those that are a conglomeration of subprojects and centrally managed by a laboratory or agency representative. Projects in this category include Next Generation Fire Suppression Technology Program and the SERDP Ecosystem Management Program.

Technical Quality Control is a recurring theme for the Scientific Advisory Board.

- Third, the Board fully supported the mid-year In-Progress Review of each project by the Technical Thrust Area Working Groups (TTAWG). While the SAB's primary function is to assess the technical aspects of SERDP projects, the Board has insufficient time to conduct a thorough technical evaluation of each ongoing project. The TTAWG is the appropriate group to perform this assessment. However, often times SAB members did attend and participate in some of the mid-year review meetings.

Commitment to Technology Transfer

The SAB continued to emphasize technology transfer potential as an important criterion for evaluating proposals. Technology transfer is one of the SERDP Keys to Success, and the Board members continued their keen interest in the role of the military Services and eventual users of the technologies being developed.

Complete technical reporting, including publications in the peer-reviewed literature as well as SERDP-required interim and final technical reports, was a metric used to determine project technical achievement and management acumen. The SAB fully supported SERDP's requirement for annual/interim technical reports and a final technical report upon completion of the project. These reports constitute technical progress to date, whether successful or not, on each project's technical approach. According to the Board, the value of "negative results" cannot be overstated, and SERDP projects should clearly state their progress and publish these results to facilitate further research.

The SAB continued its participation in the planning and execution of the annual *Partners in Environmental Technology Technical Symposium and Workshop* sponsored by SERDP. During strategy discussions at SAB meetings, the members offered comments on the overall theme of the Symposium and suggestions for technical session topics and plenary and session speakers. SAB members continued the tradition of active involvement in the planning and execution of breakout sessions. At the December 2000 event, four members served as technical session Chairs (Dr. Braden Allenby, Dr. Patrick Atkins, Dr. Raymond Loehr, and Dr. Perry McCarty) and Dr. Herb Ward served as Keynote speaker in the technical session on New Cleanup Protocols. The Board continued to demonstrate its commitment to involvement at the latest Symposium held in November 2001, with Dr. Braden Allenby serving as a technical session Chair of the Environmental Design for Maintainability, and Drs. Perry McCarty and Herb Ward providing leadership as chairs of two separate chlorinated solvents sessions. The active involvement of the SAB was a significant contributing factor to the overall success of the Symposium.

Areas of Opportunity

In the past the SAB has suggested areas of opportunity for SERDP investment. Often, these areas prove to become the focus of a national or world-wide research effort. An example of research that commenced at the suggestion of the Board is the remediation of groundwater contaminated with ammonium perchlorate. Due to their proactive thinking, SERDP was able to get a head start on understanding this phenomenon and initiating research to resolve associated issues.

During FY 2001 the SAB recommended additional candidate topic areas for future workshops, including a recommendation to the SERDP Executive Director to convene a workshop during FY 2001 devoted to Chlorinated Solvents. Held during the summer of FY 2001, this event was similar to previous SERDP workshops, in that it assessed the state of the science and progress achieved to date, identified gaps in technical knowledge, and determined strategic investment opportunities for DoD/SERDP. The results of this workshop included preparation of several Statements of Need on this topic. A second workshop was held on regional ecosystem management approaches entitled *Along The Fall Line*. This workshop focused on the need to share ecosystem management approaches and technologies between participating land managers and researchers, and to explore the potential for shared ecoregional planning and strategies at military bases located along the fall line - that area of the East Coast where rivers from upland regions drop to the coastal plain as falls or rapids.

Consistent with past practice, the Executive Director solicited the advice of the membership regarding his proposed allocation of funds among the five Thrust Areas for FY 2002. The Board was fully supportive of the proposed profile and general trends of investment within each of the five Thrust Areas.

Project Recommendations

During FY 2001, the SAB reviewed 51 proposals/projects, 38 of which were new start efforts and 13 of which were continuing projects. Of these 51 efforts, 3 requested FY 2000 funds totaling $2,019,000, 24 requested FY 2001 funds totaling $12,222,000 and the remaining 25 projects requested $11,868,000 of FY 2002 funds. The Board recommended against funding four proposals. A summary of all projects reviewed and the results of their deliberations may be found in Figure I-5.

At the September 2001 Council meeting, Dr. C. Herbert Ward, Chair of the Scientific Advisory Board advised the Council of their emphasis on enhancing the research initiation process, ensuring quality research, and fostering technology transfer to the users in the field. He was particularly pleased that proposal and project quality continue to increase and much can be attributed to an excellent and comprehensive in-process review. The independent peer review component has ensured technical quality. His encouragement reassured Council members that the Program is continuing to take the correct measures and is proceeding appropriately.

Executive Director and Program Office

Increased Emphasis on Unexploded Ordnance

For FY 2002, the Executive Director has elected to identify UXO as a separate Thrust Area. This was due to the significant technical challenges and potentially large liability for the DoD, its associated increase in the President's Defense budget to address UXO detection, and the fact that the technologies involved in UXO detection are discretely different than those used in conventional cleanup. SERDP will continue to coordinate its UXO research efforts with the DoD's Joint UXO Center of Excellence and keep abreast of new initiatives developed with the Counter Mine efforts, such as found within the Multiple University Research Initiative, or MURI. Furthermore, the UXO Program plan will undergo a thorough peer review to ensure that it properly characterizes the broad problem, establishes clear and logical goals, and identifies specific, relevant, near-term technical objectives.

Proposal Solicitation and Selection

SERDP takes pride in the fact that funds for new starts are available to industry, academia and Federal researcher alike, and the Council continues to be pleased with SERDP's ability to reach out to a broader pool of researchers through a Broad Agency Announcement. SERDP again extended two solicitations – a "Core" solicitation that has traditionally been used to develop the annual program and a SEED solicitation. The SEED Program is designed to provide initial funding for high-risk, high-payoff proof-of-concept projects.

Funding is limited to a maximum of $100,000 for up to one year. Successful efforts may compete for additional funds in the following years. Additionally, SERDP is occasionally requested to fund Congressional interest programs. In response to special requests by Congress to fund efforts in the environmental impacts of Live Fire training and perchlorate ecotoxicity research, SERDP crafted SONs to address these issues and selected proposals on a competitive basis. This process ensured that the DoD received valuable products for these limited additional appropriations.

Project No.	Recommendation		FY01 Meeting Date					New Starts	Continuing Projects
	Fund	Not Fund	1 Oct-00	2 Mar-01	3 Jun-01	4 Aug-01	5 Sep-01		
CU-861	$ 340		Oct-00						●
CU-863	$ 820		Oct-00						●
CU-866	$ 500		Oct-00						●
CU-1166	$ 445		Oct-00						●
CU-1204	$ 200		Oct-00					●	
CU-1210	$ 386		Oct-00					●	
CU-1221*	$ 365		Oct-00					●	
CU-1222*	$ 284		Oct-00					●	
CU-1223*	$ 1,370		Oct-00					●	
CU-1228*	$ 300			Mar-01				●	
CU-1229*	$ 300			Mar-01				●	
CU-1230*	$ 275			Mar-01				●	
CU-1231*	$ 260			Mar-01				●	
CU-1232*	$ 299			Mar-01				●	
CU-1233*	$ 203			Mar-01				●	
CU-1235*	$ 1,740				Jun-01			●	
CU-1236*	$ 137				Jun-01			●	
CU-1288	$ 111					Aug-01		●	
CU-1289		$ 274**				Aug-01		●	
CU-1290	$ 150					Aug-01		●	
CS-1114	$ 2,441				Jun-01				●
CS-1186	$ 391			Mar-01					●
CS-1262	$ 150						Sep-01	●	
CS-1264		$ 150					Sep-01	●	
CP-819*		$2,500			Jun-01			●	
CP-1155*	$ 399		Oct-00						●
CP-1156	$ 310		Oct-00	Mar-01					●
CP-1157	$ 164			Mar-01					●
CP-1158	$ 365		Oct-00	Mar-01					●
CP-1226*	$ 700			Mar-01				●	
CP-1227*	$ 340			Mar-01				●	
CP-1243	$ 420					Aug-01		●	
CP-1244	$ 250					Aug-01		●	
CP-1245	$ 326					Aug-01		●	
CP-1246		$ 241				Aug-01		●	
CP-1253	$ 300					Aug-01		●	
CP-1254	$ 442					Aug-01		●	
CP-1255	$ 342					Aug-01		●	
CP-1256	$ 197					Aug-01		●	
PP-1059	$ 1,000				Jun-01				●
PP-1133	$ 1,250				Jun-01				●
PP-1148	$ 350		Oct-00						●
PP-1224	$ 1,363			Mar-01				●	
PP-1268	$ 763					Aug-01		●	
PP-1270	$ 336						Sep-01	●	
PP-1272	$ 481					Aug-01		●	
PP-1280	$ 203					Aug-01		●	
UX-1225	$ 266			Mar-01				●	
UX-1281	$ 335						Sep-01	●	
UX-1282	$ 400						Sep-01	●	
UX-1283	$ 175						Sep-01	●	
TOTALS	**$22,944**	**$3,165**						**38**	**13**

* Congressional Interest **Later reviewed and recommended for funding at a FY 2002 meeting.

Figure I-5. Summary of Proposals Reviewed by SAB in FY2001 by Thrust Area.

In developing the FY 2002 program, 24 SONs were prepared, 7 of which were specifically for the SEED program. All 17 Core SONs, were made available to the private sector via a Broad Agency Announcement. The Core solicitation responded with 136 preproposals that were submitted by non-Federal participants. Of the 68 full proposals that were requested, 18 were selected for funding resulting in a 26 percent selection rate. This figure exceeded the Council's target of 20 percent and was much greater than that experienced in other programs, such as those funded by the National Science Foundation. The Federal sector submitted 83 full proposals of which 19 were selected for a 23 percent selection rate. Figure I-6 depicts the distribution of Core proposals selected during the FY 2002 program development process.

Thrust Area	No. of Statements of Need	No. of Proposals Selected	SOURCE			Approximate Value (Thrust Total)
			Federal	Academia	Private	
Cleanup	2	7	1	4	2	$1.7 million
Compliance	3	13	7	0	6	$2.6 million
Conservation	4	7	4	3	0	$1.1 million
Pollution Prevention	6	7	6	0	1	$2.5 million
UXO	2	3	1	2	0	$0.9 million
Total	17	37	19	9	9	$8.8 million

Figure I-6. FY 2002 Core New Start Proposal Distribution by Thrust Area.

The solicitation for FY 2002 SEED proposals resulted in the submission of 95 proposals. Twenty-nine percent were received from industry, 20 percent were from academia, and 51 percent came from Federal sources. While only 14 proposals were selected for funding, each exhibited the prerequisite characteristics of innovativeness, high risk and potentially high payoff. Figure I-7 depicts the distribution of all SEED proposals selected during the FY 2002 program development process.

Thrust Area	No. of Statements of Need	No. of Proposals Selected	SOURCE			Approximate Value (Thrust Total)
			Federal	Academia	Private	
Cleanup	2	3	2	0	1	$0.3 million
Compliance	0	0	0	0	0	$0.0 million
Conservation	1	3	3	0	0	$0.3 million
Pollution Prevention	3	4	1	1	2	$0.4 million
UXO	1	4	1	2	1	$0.4 million
Total	7	14	7	3	4	$1.4 million

Figure I-7. FY 2002 SEED New Start Proposal Distribution by Thrust Area.

Technology Transfer

Successful technology transfer may be used as a metric to measure the success of the Program. While having funded over 300 individual projects, not all have been technically successful, as would be expected for a research program. For those projects that were successful, several avenues were taken to ensure that the diligent efforts of the research teams were transitioned to either higher development programs or implemented directly into field use.

Technology transfer and transition continued to be a primary area of focus during annual project reviews by both the SAB and the TTAWGs. Principal investigators were tasked to prepare Annual Technical Reports that serve as a fundamental baseline of technical progress. At the end of each project, a Final Technical Report is required for each effort. These reports are maintained in a SERDP library and referenced on the SERDP website. Additionally, they are entered into the Defense Technical Information Center (DTIC) in both a hard copy and electronic version. DTIC provides all researchers with copies of these reports. Recently, SERDP has become a partner in the new EnviroScience Electronic Print (e-Print) Service. The Environmental Science Electronic Print (e-Print) Service is a joint project of DOE's Environmental

Management Science Program (EMSP), the EPA Office of Research and Development (ORD), the DoD's Environmental Security Technology Certification Program (ESTCP), and SERDP. e-Print uses EPA's Environmental Information Management System to collect, store and access published and unpublished manuscripts, conference papers, presentations and posters. This joint effort should have the result of enhancing scientific collaboration; speeding the dissemination of research findings; providing effective access to relevant research across the agencies.

The SERDP website also maintains links to websites developed by SERDP researchers. SERDP also has posted Fact Sheets on the website for every SERDP funded project. The Fact Sheet includes summaries of the technical accomplishments and potential benefits of each project.

Each year, SERDP, in cooperation with ESTCP, hosts the *Partners in Environmental Technology Technical Symposium and Workshop*. This event has, for the past six years, attracted hundreds of researchers, technology developers and users, and regulators to meet in a collegial and informative setting. In November 2000, the annual Symposium once again succeeded in providing an excellent technology transfer and networking forum for researchers, scientists, and engineers from both the Federal laboratory system and the non-Federal sector alike. Our venue focused on "Environmental Challenges for the Next Decade" in recognition of the fact that while significant advances have been made in addressing environmental issues, additional challenges are expected over the course of the next decade. This event brought 562 technology developers and implementers together, as well representatives from the policy, programmatic, regulatory, academic, and industrial sectors. The Executive Director issued the second annual SERDP Project of the Year Awards, which were given to the best projects in each of the four Thrust Areas for FY 2000. These awards have successfully attracted the attention of the scientific and engineering community around the globe and have measurably helped to either transition this technology into higher development programs, or implement its use in field applications. This conference, which has received numerous accolades, will continue to be enhanced to serve as a significant technical, educational and technology transfer event.

Plans for FY 2002

In FY 2002, SERDP will aggressively respond to the increasing challenges of environmental issues impacting training and testing activities as well as the remediation of lands contaminated with UXO. Specifically, in response to the President's amended FY 2002 budget request and subsequent Congressional changes SERDP issued a second set of SONs to address these issues. Areas to be funded under this solicitation include:

- Develop advanced approaches to UXO detection, discrimination, and remediation;
- Develop site characterization and UXO remediation technologies for underwater sites;
- Further study the fate and transport and containment/treatment of energetics;
- Evaluate the impacts of military aircraft noise;
- Assess the impacts of training activities and management actions on terrestrial threatened and endangered species (TES); and
- Research environmentally acceptable components for medium caliber munitions.

Other activities that SERDP plans to actively pursue in FY 2002 include:

- In early FY 2002, SERDP issued SONs for projects to be funded in FY03 (see Appendix F for full listing of SONs). Areas of interest for funding in FY03 include:

  – Cleanup - Source zone delineation, characterization, and remediation of chlorinated solvents and evaluation of the sequestration and bioavailability of metals.

  – Compliance - Non-point source surface water runoff from military lands and air emissions from off-road diesel vehicles.

- Conservation - Impacts of military activities on TES, characterization of benthic species communities, and estuarine ecosystem management and restoration.

- Pollution Prevention - Environmentally acceptable alternatives to chrome coating systems, nickel electroplating, metal parts cleaning, and liquid spray paint components. Environmentally acceptable techniques for the removal of RAM coatings, energetic synthesis techniques, and components of medium caliber munitions.

- UXO - Given the overwhelming response to the UXO SONS issued for the planned as well as the supplemental solicitations in FY 2002 and the large number of projects that are expected to be funded, no SONS will be issued for new start UXO projects in FY 2003.

• SERDP will evaluate the results of the Chlorinated Solvents Workshop to develop future SONs to address data gaps and remaining issues of concern identified in this workshop.

• SERDP will conduct a Sustainable Range workshop to identify opportunities for research to address increasing constraints on military testing and training activities on military ranges.

• SERDP plans to conduct special studies and gap analyses to identify future opportunities for research and potential opportunities for integration/collaboration to address unmet high-priority research needs.

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II. SIGNIFICANT ACCOMPLISHMENTS

Introduction

SERDP continues to be a leader in the field of environmental research and development by providing solutions to both new and persistent environmental matters of concern to the Department of Defense (DoD) and the Department of Energy (DOE). With an effective outreach program that includes technology gap analysis studies, SERDP strives to remain ahead of the curve on identifying high-priority and emerging requirements. SERDP has supported almost 400 science and technology projects since the Program's inception in 1991 in the areas of cleanup, compliance, conservation, pollution prevention, and unexploded ordnance. These projects have enabled DoD installations to meet their environmental responsibilities using cost-effective and innovative methods. During FY 2001, SERDP continued to play a critical role in the development of science and technology that supports the DoD's environmental security mission.

A selection of SERDP's most significant accomplishments during FY 2001 are described in this section. While these projects represent but a small slice of the many innovative projects supported by SERDP, they demonstrate the breadth and depth of the program and highlight the types of major technical advances resulting from focused research and development. Moreover, many of these accomplishments illustrate potential cost savings resulting from full implementation of new technologies while simultaneously maintaining mission readiness. Appendices A through F provide a summary of each SERDP project funded in FY 2001, new projects funded for FY 2002, and new initiatives planned for FY 2003.

Cleanup Accomplishments

In-Situ Bioremediation of Perchlorate Impacted Groundwater

Groundwater contamination related to the production, handling, and use of rocket propellants such as ammonium perchlorate has been identified as a widespread problem at DoD, DOE, National Space & Aeronautics Administration (NASA), and defense contractor facilities. It is estimated that perchlorate has been manufactured and/or used in 44 states, resulting in groundwater contamination in at least 14 of these states. In California, Arizona, and Nevada alone, it is estimated that perchlorate impacts the drinking water supplies of more than 15 million people. The concern surrounding perchlorate in groundwater and drinking water supplies relates to its ability to impact thyroid function. Starting in FY 2000, SERDP funded three projects to focus on the basic microbiology, bench-scale, and field-scale research to develop biological approaches for the cost effective, in-situ treatment of groundwater contaminated with perchlorate. These three research teams have worked closely with one another and as a result have made significant progress in developing methods for the remediation of perchlorate impacted groundwater. In recognition of these efforts, the three project teams were selected for a combined SERDP Project of the Year Award in FY 2001. Collectively, these studies and demonstrations provide the first extensive evaluation of the potential for in-situ bioremediation of perchlorate at DoD sites.

Through project **In-Situ Bioreduction and Removal of Ammonium Perchlorate (CU-1162)**, researchers from Southern Illinois University (SIU) investigated the microorganisms that degrade perchlorate. The enumeration studies of perchlorate-reducing bacteria that were performed on samples collected from a broad diversity of environments demonstrated that microbial perchlorate reduction is ubiquitous in the environment. SIU researchers isolated and characterized more than 30 perchlorate-reducing bacteria that thrive in both acidic and alkaline sites, and the dominant groups found in most environments have been identified. The SIU researchers have identified and elucidated the enzymes involved in the degradation of perchlorate in these organisms.

As part of the technology transfer application of this research, the SIU team worked to develop a universal probe for rapid detection of perchlorate reducing bacteria in soil. To develop the probe, SIU researchers conducted several kinetic studies in pure culture to determine if all perchlorate-reducing bacteria contain the chlorite dismutase enzyme which is essential for the reduction of (per)chlorate as it catalyzes the dismutation of toxic chlorite into chloride and oxygen (see Figure II-1). These kinetic studies have allowed the SIU researchers to isolate and sequence the chlorite dismutase gene and develop a universal gene probe to detect perchlorate-reducing bacteria.

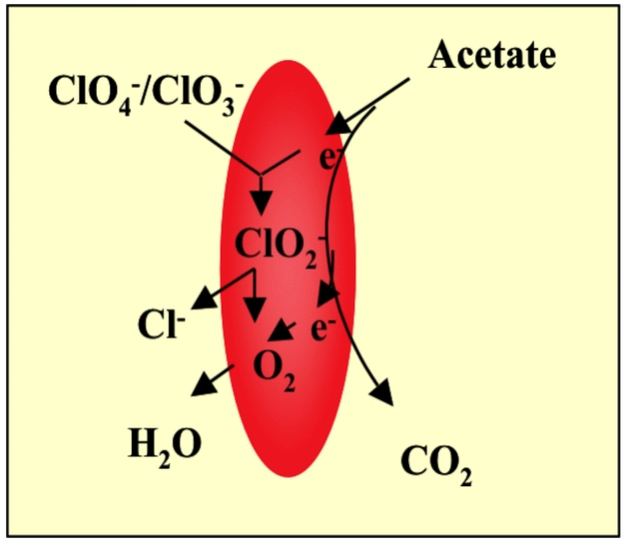

Figure II-1. The Chlorite Dismutase Enzyme is Functional in all (Per)Chlorate-Reducing Bacteria.

Researchers at Envirogen, Inc., conducted laboratory studies under the project **In-Situ Bioremediation of Perchlorate (CU-1163)** to develop the fundamental knowledge required for designing and implementing in-situ bioremediation technologies at perchlorate-contaminated sites. Factors evaluated included the following: (1) the most effective substrates for stimulating perchlorate reduction by naturally-occurring bacteria; (2) the role of alternate electron acceptors, such as nitrate, ferric iron, and sulfate on perchlorate reduction; and (3) the impact of co-contaminants and environmental factors on perchlorate biodegradation. Microcosm studies were conducted using soil and water from several perchlorate-contaminated sites across the U.S. The data revealed that perchlorate-reducing bacteria are widely distributed in groundwater environments with differing geochemistries, and with the addition of appropriate substrate, these organisms in most cases can be stimulated to degrade perchlorate to below detection limits. A kinetic model of perchlorate biodegradation was developed using aquifer columns (see Figure II-2) that describes the degradation of perchlorate in the presence of competing terminal electron acceptors. This model will be incorporated into an existing reactive transport model to be used as a tool for describing perchlorate transport and degradation at the laboratory and field scale.

Figure II-2. Laboratory Setup of the Aquifer Column Studies and Modeling to Understand Perchlorate Transport and Biodegradation.

Using information obtained in the two projects described above, researchers from GeoSyntec Consultants, Inc., will conduct a field pilot test in FY 2002 to demonstrate in-situ bioremediation of perchlorate using an active groundwater capture, amendment, and recharge approach. Under the project **In-Situ Bioremediation of Perchlorate-Impacted Groundwater (CU-1164)**, perchlorate-impacted groundwater will be extracted via two extraction wells. The extracted groundwater will then be combined and approximately three times the amount of ethanol and/or acetate that is required to reduce the oxygen, nitrate, and perchlorate will be added. It is then reinjected into the ground daily to the same depth interval of the aquifer. Using this innovative technique, the interspaced capture and recharge wells form a biobarrier across the plume that prevents further migration of the perchlorate plume in this area (see Figure II-3).

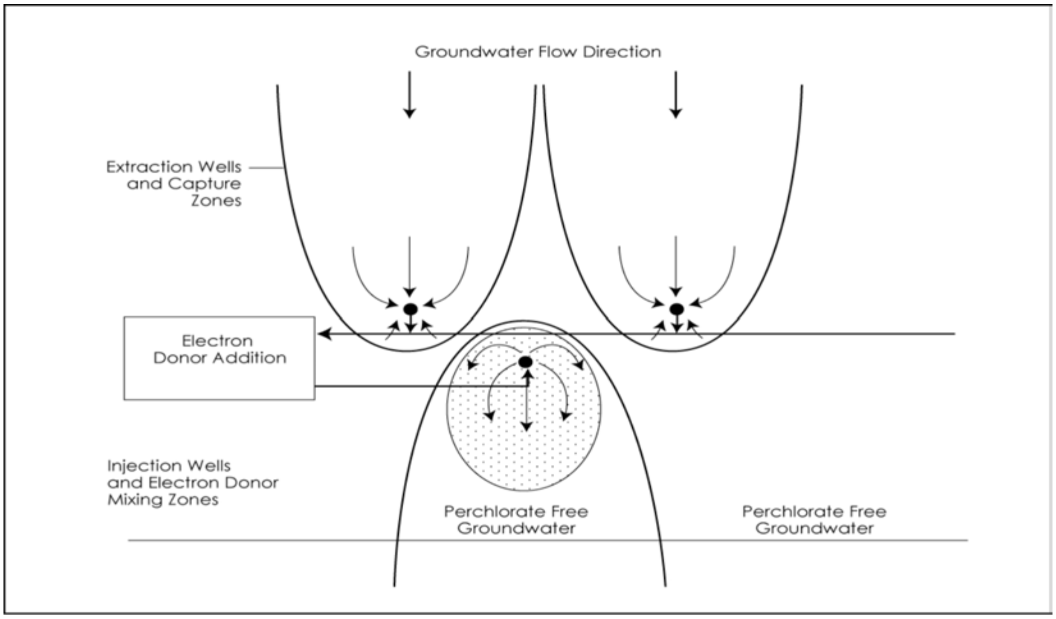

Figure II-3. Schematic of a Small-Scale Field Pilot Test at One Site to Demonstrate that Perchlorate Can Be Biodegraded under Field Conditions.

Chlorinated Solvent Expert Workshop

Chlorinated solvents are by far the most prevalent contaminants at DoD facilities and remain among the most difficult to remediate, despite several years of research and development. Examples include trichloroethylene (TCE) and perchloroethylene (PCE), as well as related compounds such as trichloroethane (TCA), vinyl chloride (VC), dichloroethenes (DCE), and carbon tetrachloride (CT). To evaluate the needs and priorities for future research and development in support of chlorinated solvent site cleanup, SERDP and the Environmental Security Technology Certification Program (ESTCP) convened a panel of 23 experts August 6-7, 2001. The overall objective of the workshop was to provide guidance as to how SERDP and ESTCP can best invest their research, development, and demonstration resources in the next 5-10 years to improve DoD's ability to address its solvent-contaminated sites effectively.

During the two-day workshop, participants were asked to identify the major gaps in scientific understanding of chlorinated solvent contamination and cleanup, the most important basic and applied research needs, and the specific technical issues that must be addressed to meet regulatory and other stakeholder concerns. The participants also were tasked with prioritizing these research needs and identifying those areas with the greatest potential to help DoD accomplish its goals. Participants then were divided into two groups to facilitate focused discussions on the science and technology needs for groundwater plume restoration and non-aqueous phase liquid (NAPL) source remediation.

Results of the workshop revealed that research and development of NAPL source treatment technologies was considered far more important at the present time than improved treatment approaches for the groundwater plumes that emanate from the source. Recent development of more aggressive source-zone treatment technologies has led to increasing regulatory and public pressure to remediate source zones, despite significant scientific uncertainties about the value of source-zone remediation or even the availability of appropriate methods to measure or define the "success" of such efforts. To measure the impacts of source treatment or to understand the real risks posed by a residual source, accurate estimates of the total NAPL mass and the mass release before and after treatment are essential. Workshop participants voiced a clear overall priority for research and development of diagnostic tools to assess the performance of source-zone treatment technologies. Many participants emphasized that better use of existing technologies would be more valuable than the development of still newer technologies and that guidance is clearly needed in the selection, design, and implementation of available technologies. In terms of specific remedial technologies, the group considered thermal and bioremediation treatment as the most promising areas for future investments of research funding. Further, monitored natural attenuation (MNA) and enhanced bioremediation were regarded as important because they are likely to be part of treatment trains for source zone remediation, in many cases following more aggressive technologies. Finally, there was a recommendation for increased efforts in technology transfer.

A detailed formal report that summarizes the results of the Chlorinated Solvent Expert Workshop is in progress and will be disseminated once finalized. Results from this workshop will influence future SERDP and ESTCP solicitations and the Programs' activities in the years to come.

The NETTS Program Hosts Successful R&D Projects

The SERDP National Environmental Technology Test Site (NETTS) program is comprised of a network of well-characterized demonstration sites at DoD installations. The goal of this SERDP-funded program is to provide accessible, well-supported field locations for project proof-of-principle tests, applied research, and comparative demonstrations, as well as to facilitate transfer of innovative environmental technologies from research to full-scale use. Established in FY93, the SERDP NETTS sites are available to DoD, as well as other federal agencies and the private sector. Of the many demonstrations that were hosted at the NETTS locations during the last fiscal year, a couple of key successes related to demonstrations at NETTS locations in FY 2001 are detailed below.

In-Situ Bioremediation of MTBE in Groundwater -- Port Hueneme

In-situ containment and treatment of methyl tertiarty butyl ether (MTBE)-contaminated aquifers is becoming increasingly important to both the private and public sectors. MTBE is a common fuel additive that has emerged as a major groundwater contaminant. Innovative treatment methods are being developed and studied because the effectiveness of traditional treatment options may be limited by MTBE's unique chemical properties. For the past two years, ESTCP has been sponsoring a large-scale MTBE plume containment demonstration at the **National Test Site Location at Port Hueneme (CU-863)**. Researchers from the Naval Facilities Engineering Service Center (NFESC) and Arizona State University conducted the demonstration.

This passive flow-through biobarrier system was designed to degrade MTBE and other dissolved hydrocarbons leaving the down-gradient edge of a residual gasoline-impacted source zone (see Figure II-4). This site is somewhat unique in that the dissolved MTBE plume is approximately 500 feet wide and about a mile long. Dissolved MTBE concentrations up-gradient of the biobarrier are as high as 10 ppm, and petroleum hydrocarbon compounds from a gasoline spill are also present in large concentrations in the central core of the plume. Several different combinations of bioaugmentation and air and oxygen biostimulation are being evaluated in this large-scale demonstration.

Figure II-4. System Layout of the Passive Flow-Through Biobarrier System.

The treatment performance of the biobarrier system has been exceptional. Groundwater treatment efficiencies for both MTBE and BTEX in excess of 99.9% have been achieved and sustained during the first 12 months of operation. The MTBE concentrations down gradient of the biobarrier are less than 5 ppb. MTBE and other dissolved petroleum hydrocarbons from gasoline are being converted to innocuous carbon dioxide and water. No wastes are being generated and no water disposal is necessary. Operational and maintenance costs are low, and power requirements are minimal. Through the coordination efforts of the Port Hueneme NETTS, this demonstration has been extremely visible at the national level and was recently awarded the prestigious 2001 Outstanding Ground Water Remediation Project Award from the National Ground Water Association.

Passive Diffusion Membrane Sampler Technology -- McClellan AFB

Researchers at **the National Test Site Location at McClellan AFB (CU-861)** recently completed a full-scale demonstration of an innovative approach for collecting groundwater samples using passive diffusion membrane groundwater samplers developed by the U.S. Geological Survey (USGS). The technology uses a low-density, water-filled polyethylene diffusion membrane to collect groundwater samples for volatile organic compound (VOC) analysis (see Figure II-5). The membrane allows VOCs in contaminated groundwater to diffuse into the initially uncontaminated deionized water sealed within the membrane. The 1.5-foot long samplers are attached to a weighted rope, lowered into a groundwater monitoring well, and left in place for a minimum of 14 days to attain VOC equilibrium between well water and the deionized water within the samplers. Upon recovery, the samplers are cut open and samples poured into standard 40-milliliter sample vials for submission to a lab for VOC analysis.

Figure II-5. Diffusion Membrane Sampler Size as Compared to Standard Ruler Pictured at the Bottom.

The evaluation concluded that the VOC concentrations reported in the diffusion samplers were statistically equivalent to conventional sampling results. In many cases, diffusion sampler results provided data that appeared to be more representative of the true nature of VOC contamination in the groundwater immediately adjacent to the well screen. Since this is a passive sample collection technique, significant cost savings can be achieved primarily as a result of the decrease in labor required for purging during sampling events. When compared to conventional groundwater purge-and-sample collection techniques, the diffusion samplers have demonstrated the potential to save between $275 per sample when purge water can be treated on-site and $600 per sample when purge water must be disposed of off-site.

The diffusion sampler devices tested at McClellan Air Force Base were provided by the USGS, but several vendors recently have been granted licensing rights to commercialize the samplers. Based upon the results of these two studies, McClellan NETTS staff have proven that the diffusion samplers are ready for commercialization. McClellan AFB has received approval to implement the use of diffusion samplers by Region IX of the U.S. Environmental Protection Agency (EPA) , the State of California Department of Toxic Substances Control, and the State of California Central Valley Regional Water Quality Control Board.

Compliance Accomplishments

Energetic Materials in the Environment

While the issue of "sustainable ranges" recently has gained visibility, SERDP has invested in research to address the need for sustainable ranges for the last decade. Most recently the focus has been on the nature and extent of contamination and the fate of residues of energetic materials released during testing and training activities. The SERDP project, **Distribution and Fate of Energetics on DoD Test and Training Ranges (CP-1155)**, is identifying range activities that result in residues of explosives that may have the potential to contaminate groundwater. Researchers from the Department of the Army's Engineer Research and Development Center have devised a novel approach to assess the potential for groundwater contamination from residues of explosives (TNT, PETN, RDX, and HMX) by sampling impact craters on active ranges and by conducting detonations on pristine snow. Environmental transport parameters and the distribution and concentration of the residues are being developed based on snow, soil, and water samples. These data then are used to estimate site-specific source terms for use in risk assessment and groundwater transport models.

Figure II-6. One-Meter Square Samples on Snow Cover.

The use of snow-covered ranges to determine the explosives residues is a highly efficient and cost-effective method of characterization. The snow cover provides an uncontaminated surface, a visible soot marker that delineates the area where residues are deposited, and a convenient matrix for collection of large surface area samples which is essential for characterizing heterogeneously distributed residues (see Figure II-6). Preliminary results suggest that range management may need to include removal of low order detonations that disperse discrete solid phase particles onto and into the soil. Results indicate that hand grenade ranges also may require periodic soil remediation. Additionally, this project has determined the kinetics and sorption process descriptors for nitroglycerin; 2,4- and 2,6-dinitrotoluene; 1,3,5-trinitrobenzene; 1,3-dinitrobenzene; and the transformation products of RDX, MNX, DNX, and TNT. These descriptors are critical to define accurately the fate and transport processes for soil under conditions of short-term water saturation. The contribution of this project works toward substantially reducing the cost of site characterization and the risk of contamination from range activities.

Understanding the mass transfer rate from energetic material into the soil pore water is critical for defining the impact of energetic residues on groundwater contamination. This allows for an inclusion of an energetic material source release function into a soil solute transport simulation code, and thereby, creates a new predictive capability to assess the migration potential of energetic materials. The SERDP project **Measurement and Modeling of Energetic Material Mass Transfer to Pore Water (CP-1227)** is developing a source release function that describes the mass transfer of solid energetic materials to soil pore water (see Figure II-7). This function then is used in a transport model that links time dependent weather phenomena that are known to control the transport process. This project is well on its way to developing a predictive simulation tool using specific data that define an energetic material source release function. Once fully developed, the tool can be used to assess groundwater pollution management strategies for residual energetic materials left by military testing and training operations.

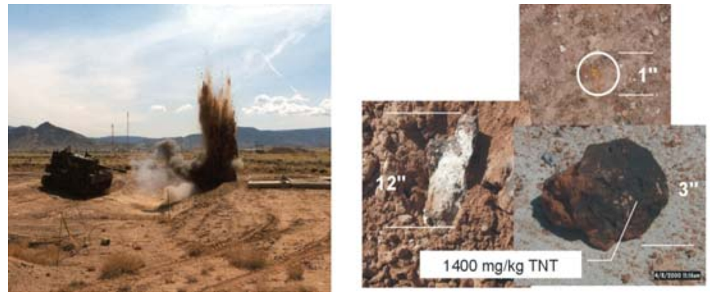

Figure II-7. Discrete Solid Phase Particles of TNT Are Dispersed in a Low Order Detonation.

Solid Waste and Wastewater Treatment

A typical 300-man Navy vessel produces more than 16,000 gallons of wastewater per day. Domestic and commissary functions, as well as industrial and machinery maintenance activities, generate this wastewater, which is comprised of gray water, bilge water, and black water. Tightening federal and state water quality standards and stricter regulation of foreign ports and harbors continue to increase the cost of waste off-load, on-site treatment, and compliance with foreign and domestic environmental regulations. In 1995, the Navy spent a total of $63M to off-load and dispose of ship-generated wastewater. Without any change to the process, this translates to $1,490M over the next 20 years to off-load and dispose of shipboard wastewater.

Historically, membranes have been used extensively to filtrate wastewaters. When fed under pressure, suspended solid wastes and other colloidal and particulate matter of the wastewater are retained by size exclusion in the membrane surface and in the pores. However, the wastewater tends to lodge in narrow constrictions in the porous network of existing membrane surfaces (see Figure II-8). Over time, fouling markedly decreases flow through the membrane. To address the issue of fouling by colloidal and particulate matter, SERDP funded the project **Novel Nonporous Fouling-Resistant Composite Nanofiltration Membranes and Membrane Separation Systems for Wastewater Treatment (CP-1108)**. Under this project, researchers at North Carolina State University and Membrane Technology and Research, Inc., applied a thin, nonporous, hydrophilic polymer to the surface of a conventional porous polymer to form a fouling-resistant composite membrane. The polymer coating serves as a barrier to prevent particulate matter from reaching the interior pore structure, thereby minimizing or eliminating internal fouling. A high water flux can be maintained and the membrane has proven to be mechanically and chemically robust.

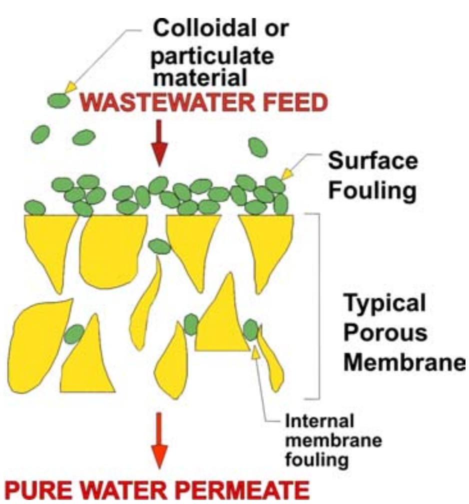

Figure II-8. Typical Membrane Filtration Process.

The microporous support layer is similar to conventional porous membranes and is made of poly vinylidene fluoride, an engineering polymer endowed with very high chemical stability. The sub-micron nonporous coating on top of the porous support membrane is Pebax, a block copolymer composed of highly hydrophilic polyether segments and high strength nylon segments. Results show a remarkable improvement in the capabilities of the coated membrane relative to conventional membranes. These initial results suggest that a shipboard water treatment system designed with the coated membrane could be 10 times smaller than that based on the conventional porous membrane which is an important consideration for Navy ships where space is a premium. This project was recognized and awarded the SERDP Compliance Project of the Year Award for FY 2001 at the *Partners in Environmental Technology Technical Symposium & Workshop* held November 27 - 29, 2001.

Marine Environmental Issues

Some forms of the metal copper (Cu) are toxic to phytoplankton and bottom-dwelling organisms and to the higher levels of the food chain that feed on these organisms in the marine environment. The ecological impact of this trace metal depends critically upon its physical and chemical speciation and exposure routes. Many industrial and non-point source effluents, including discharges from DoD facilities, ships, and small craft, can release Cu into the marine environment. The U.S. EPA has established water quality criterion for dissolved Cu based on the concentration of total copper concentrations instead of the concentrations of free Cu, which is believed to be the primary toxic specie to organisms. Consequently, the water quality criterion of Cu may be overly conservative in a variety of conditions. A fundamental understanding of the relationships between Cu sources, levels, speciation, and bioavailability is needed to properly define future approaches to Cu regulations.

In order to examine the distribution, fate, and toxicity of Cu from DoD-related sources, SERDP has funded three collaborative projects. Most notably, these projects have agreed upon a common sampling and analysis protocol for measuring Cu and zinc (Zn) speciation. The SERDP project **Determining the Fate and Ecological Effects of Copper and Zinc Loading in Estuarine Environments: A Multidisciplinary Approach (CP-1156)** is developing a method for estimating the ecological impact of Cu and Zn loading on estuarine environments, specifically in mixing zones within the San Diego Bay. This effort, led by the Navy Space and Naval Warfare Systems Command (SPAWAR) Systems Center in San Diego, is applying a hydrodynamic (physical) estuarine model that simulates estuarine topography, tidally-driven currents, meteorology, and bottom characteristics (see Figure II-9). The model is being modified to compute water residence times for Cu and Zn species in the estuary, the key physio-chemical variable against which all other rate-dependant processes are evaluated. Preliminary results indicate a relationship between toxicity and the capacity for ligands to complex with Cu. The results also indicate that the distribution of total copper and complexed Cu in San Diego Bay is a direct function of the residence time of the water in the bay. Preliminary modeling results indicate that tidal flushing and sedimentation are of roughly equal importance in the overall concentration of total copper in San Diego Bay. They also indicate that water residence time and complexation capacity of Cu within the bay occur on approximately the same time scale.

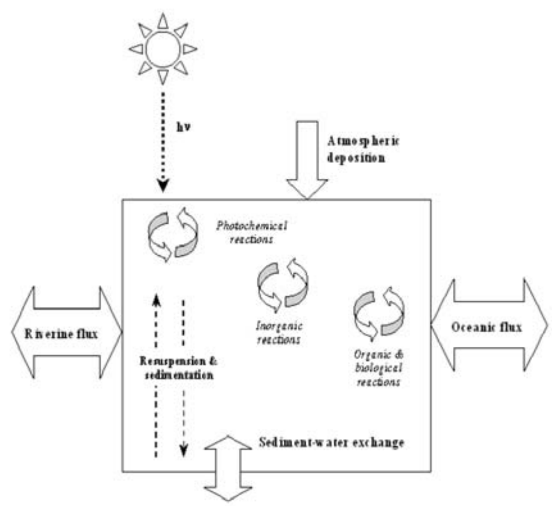

Figure II-9. Simplified Model of Cu and Zn Behavior in Estuaries.

The SERDP project **Speciation, Fluxes, and Cycling of Dissolved Copper and Zinc in Estuaries: The Roles of Sediment Exchange and Photochemical Effects (CP-1157)** is examining the fluxes and controls on the speciation of the dissolved forms of the potentially toxic trace metals, Cu and Zn, in the organic-rich Cape Fear Estuary in southeastern North Carolina. The Cape Fear Estuary has a significant excess of very strong Cu-complexing organic compounds, known as ligands, relative to the amount of ambient dissolved free Cu. Hence, the Cape Fear Estuary may be considered to be relatively "well-buffered" with respect to potentially toxic free Cu because of these ligands. Researchers from the University of North Carolina have detected movement of Cu-complexing ligands from sediments into the overlying water column. Bacterial and phytoplankton pigments are being used as sediment markers to identify ligand sources and further test these initial findings. Most of the strong Cu-complexing ligands are derived from the very small size fraction of the sediment. This observation contrasts with previous observations in less organic-rich estuaries, in which most Cu-complexing ligands were found to be in the dissolved fraction. The photochemical reactivity of dissolved Cu and Cu-complexing ligands in the Cape Fear Estuary also is being examined. Initial results indicate that a significant fraction (~20%) of Cu-complexing ligands degrade under solar irradiation. However, a class of extremely strong ligands was apparently not degraded. These and other experiments suggest that very strongly complexed Cu may not be photoreactive, whereas weaker complexes may be more reactive. The significance of these photochemical reactions on Cu speciation, reactivity, and cycling in estuarine waters will be investigated through on-going research efforts.

The overall goal of the SERDP project **Speciation, Sources, and Bioavailability of Copper and Zinc in DoD Impacted Harbors and Estuaries (CP-1158)** is to advance the current understanding of the fate and impact of Cu and Zn in harbors and estuaries that might potentially be impacted by DoD activities. The lability (i.e., reactivity) of Cu and Zn within "pools" or sinks in which these trace metals can accumulate has been characterized using several complementary techniques, including electrochemical and resin-based methods. The bioavailability of Cu in specific pools was determined with three species of marine algae using both molecular and whole organism bioassay endpoints. Lability measurements are complemented and validated by bioassays at both the molecular and organism level. Stable isotopes of Cu and Zn are being evaluated as tracers of source and source-specific bioavailability. Early results indicate that predictable and reproducible relationships exist between the Cu bioavailability measures and concentrations of strong and weak ligands. Progress also is being made on identifying the source and nature of the metal-binding ligands. These results strongly support efforts to develop speciation-based water quality criteria.

The active collaboration and interaction of these projects provides a unique opportunity to develop a variety of methods to assess the fate and transport of Cu in estuaries. DoD can use this information to evaluate the impact of releases of these metals into the estuarine environment.

Conservation Accomplishments

Ecosystem Restoration

Seventy percent of DoD training and testing areas are located on arid and semi-arid land. Testing and training activities can impact land sustainability and, consequently, can threaten the continuation of military testing and training operations. Within the DoD, the military services are required to maintain and restore remaining native ecosystems and to ensure the long-term sustainability of military training and testing lands and waters in support of the National Defense mission (DoD Instruction 4715.3). Gaps exist in our diagnostic capabilities to distinguish between various degrees of sustainable and non-sustainable ecosystem impacts from military activities. The SERDP project **Diagnostic Tools and Reclamation Technologies for Mitigating Impacts of DoD/DOE Activities in Arid Areas (CS-1131)** has been extremely successful in developing innovative diagnostics that will rapidly characterize sustainable and non-sustainable impacts of military training and testing activities on these lands. Diagnostic techniques, developed by DOE Special Technologies Laboratory/Bechtel Nevada, provide a means to bridge the gap between limitations in the use of remote-sensing/satellite imagery and the high cost and time required to perform detailed ground surveys of the status of ecosystems on military lands. The diagnostic tool kit developed by this project will aid installation managers in evaluating and monitoring the resiliency of a training range to disturbances by rapidly assessing vegetation shrub density, height, diameter, size class, and percent canopy cover.

Figure II-10. LIFI System Prior to Deployment.

The kit is a combination of techniques for image collection and processing to assess vegetation damage and recoverability. Using hand-held digital cameras and Hi-8 mm camcorders, selected ground data such as shrub height and canopy width can be recorded. Images shot from helicopter or fixed-wing aircraft along selected or permanently marked flight lines are evaluated using computer technologies to provide rapid assessment of vegetation. Both aerial data and satellite data (IKONOS) are integrated using image-processing software. In addition, a laser-induced fluorescence imagery (LIFI) technique (see Figure II-10) developed by Special Technologies Laboratory/Bechtel Nevada, allows a rapid assessment of living plant tissue. The LIFI technology works on the principle of fluorescence of the chlorophyll in vegetation when illuminated by a pulse laser. Other reflectance wavelengths are also characteristic of biotic crusts, desert pavement, and other soil or geological site conditions. LIFI data can be real-time, located through global positioning system instruments, and managed and displayed by geographic information system (GIS) software. The use of these techniques significantly reduces the time required to evaluate the status of training range ecosystems by several orders of magnitude, while increasing data reliability.

Ecological Forecasting

In order to reduce land use maintenance costs and increase the availability of land for military training and testing activities, accurate methods are required to forecast ecological responses to military-specific disturbances. This requires techniques to quantify and forecast the capacity of DoD lands to support military training and testing missions on a sustained basis. In 1995, the Army funded a study to develop a methodology for estimating the operation and support costs of using land at Army installations to train ground forces. An example of the effects of training operations is shown in Figure II-11. The result of this project was the Army Training and Testing Area Carrying Capacity (ATTACC) methodology. A key component of this methodology was the determination of the carrying capacity of military lands. The ATTACC methodology provided an analytical tool at the Headquarters, Department of Army level for estimating military training land carrying capacity and the costs of essential land rehabilitation and maintenance activities. The project **Improved Units of Measure for Training and Testing Area Carrying Capacity Estimation (CS-1102)** has extended the ATTACC methodology to include multiple measures of land condition and better characterization of testing and training activity impacts.

Figure II-11. Vehicle Tracked by Research Team to Obtain Land Use Patterns, and the Disturbance Left Behind.

Under this project, enhancements to the ATTACC methodology were made through the incorporation of multiple measures of land condition including wind erosion, a topographic factor for water erosion, and species composition. Significant improvements also have been made in the ability to characterize the temporal and spatial aspects of mission impacts. A framework and methods were developed to predict event-specific mission footprints based on military training doctrine. Protocols and tools were developed to model historical land use patterns, track individual vehicle land use patterns in ongoing training exercises, and utilize battlefield simulation systems and training doctrine to predict the impacts of future land use patterns. Cumulative iterations and simulations of mission activities provide landscape level impact distribution maps for specific military activities. This research effort has now transitioned to a field validation stage.

Threatened and Endangered Species

Research and development opportunities continue to address current compliance requirements under the Endangered Species Act (ESA) and National Environmental Policy Act (NEPA). The Red-Cockaded Woodpecker (RCW) (Figure II-13) is a listed endangered species as well as a keystone species whose subsistence impacts at least 30 other critical animals and plants within the fire-adapted, mature pine forest habitat in the southeastern United States. DoD units train on land that is sensitive habitat for the RCW. These training installations, 16 in total, must contend with the conflicting interests of RCW management requirements and the optimum use of training land to maintain military readiness.

Researchers at the U.S. Army Corps of Engineers Construction Engineering Research Laboratory (CERL) have observed and documented the immediate RCW response (e.g., flush from the nest cavity) and individual fitness parameters, such as reproductive success, to specific noise events under the project **Assessment of Training Noise Impacts on the Red-Cockaded Woodpecker (CS-1083).** Dose-response relationships were established between noise level and the probability of proximate RCW response behavior and reproductive success. The project's findings show that the RCW successfully acclimates to military noise events. Additionally, the noise exposure did not result in any mortality or statistically detectable changes in reproductive success.

Figure II-13. Red-Cockaded Woodpecker.

Both the U.S. Army and U.S. Fish and Wildlife Service have evaluated the project and deemed it a huge success for the following three important reasons: (1) the coordination efforts implemented early in the development of the experimental design allowed for the integration of the knowledge and interests of all concerned parties, (2) the rigorous and defensible nature of the experimental design, and (3) the usefulness and timing of the project's findings. The principle outcome of this SERDP-funded effort is a thorough authoritative assessment of military noise impacts on the RCW. This research supports the sustainability of military lands by providing a knowledge base to defend a reduction in training restrictions and a more judicious management of the RCW.

This project was recognized and awarded the SERDP Conservation "Project of the Year" Award for FY 2001 at the *Partners in Environmental Technology Technical Symposium & Workshop* held November 27 - 29, 2001.

Ecosystem Processes

Under the management of U.S. Army Engineering Research and Development Center, the **SERDP Ecosystem Management Project (SEMP) (CS-1114)** continues to support DoD's commitment to maintain and improve the sustainability and native biological diversity of terrestrial and aquatic ecosystems. SEMP is an umbrella-type project implementing a long-term ecological monitoring program and is supporting research and development focused on the identification of ecological indicators, disturbance regimes, ecological thresholds, and adaptive management. The goal of SEMP is to provide knowledge, tools, and techniques to contribute to the understanding and enhancement of the ecological impacts of military installations within their ecoregions.

In FY 2001, significant accomplishments were reported for the first set of three research projects that commenced in FY 1999 to identify and link indicators of ecological change to processes that occur as a result of natural or military events/activities. Relationships among ecological indicators and land condition are being evaluated through sampling efforts across Ft. Benning. Samples are collected from sites with a range of military and non-military land uses and anthropogenic disturbances. From these analyses, a list of promising indicators of ecological change has been identified.

An example of the type of progress resulting from the individual research efforts addressing ecological indicators is the SEMP project, **Indicators of Ecological Change**. Under the leadership of DOE Oak Ridge National Laboratory, researchers on this project investigated a suite of variables to measure change in ecological conditions across multiple scales and disturbance gradients. The suite includes measures of landscape patterns, terrestrial biological integrity, stream chemistry and aquatic biological integrity, and soil microorganisms. Baseline landscape conditions were established from historical land survey maps and field notes from the early 1800s. Several sources of remotely sensed data were used to create land cover maps dating back to the 1970s. From these maps, candidate landscape metrics that describe a diversity of land use types and how they may affect land management activities have been selected for analysis. Preliminary results of stream studies indicate that stream suspended sediment concentrations during storms appear to be a good indicator of ecological disturbance, with greater increases in suspended sediments occurring in the most disturbed watersheds. Diurnal change in stream dissolved oxygen concentrations may be a useful indicator of disturbance effects as well. The total number of invertebrate species and the presence of species from the orders Ephemeroptera, Plecoptera, and Trichoptera (EPT richness) were not indicative of the degree of disturbance. However, the abundance of focal populations (i.e., the number of sediment-tolerant chironomid midges) was higher in disturbed streams and thus appears to be a useful indicator of sediment disturbance. The understory characteristics of sites with different training intensities showed that microbial biomass in the soil decreased with increasing levels of disturbance. Analysis of 137 plant species sampled in the understory shows that the highest diversity is in the light training areas. A significant number of species are found only in the light training and reference sites. Of the various life forms examined, geophytes seem particularly likely to sustain themselves under disturbances from military activities.

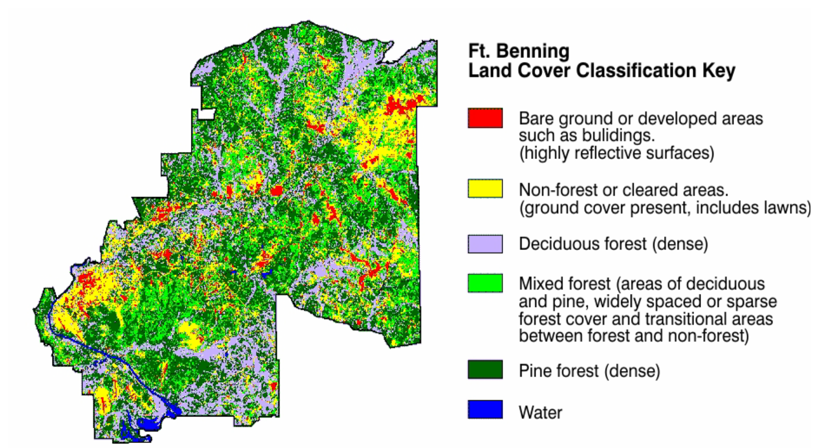

Figure II-14. Image of the Varying Land Cover over Ft. Benning, GA.

Further information on all of the SEMP projects is available at http://www.denix.osd.mil/SEMP. This web site includes a calendar of activities, links to other sites, selected SEMP briefings and publications for review and for downloading, and a discussion forum.

Pollution Prevention Accomplishments

Next Generation Fire Suppression

Fire suppression is essential to the readiness and effectiveness of nearly all weapon systems. Halon 1301 (CF_3Br) has a high ozone depletion potential and thus has been out of production since January 1994. Inefficient near-term alternatives for both backfit and new systems make Halon phase-out difficult because of serious weight and volume penalties, as well as having operational and financial impacts. The **Next Generation Fire Suppression Technology Program (NGP) (PP-1059)** is attempting to demonstrate by 2005 technology for economically-feasible, environmentally-acceptable, and user-safe processes, techniques, and fluids to meet the operational requirements satisfied by Halon 1301 systems in aircraft. Through SERDP sponsorship, the National Institute of Standards and Technology (NIST), Gaithersburg, MD has led a team of government, academic, and industrial scientists in identifying new chemicals and improving the effectiveness of their delivery to the fire.

There are a large number of objective cost factors and subjective value factors that must be considered when selecting a fire suppression system. The NGP has developed a methodology, as presented in Figure II-15, to compare alternative fire suppression technologies by their total life cycle costs and to enable superimposing a subjective value system on this comparison. The methodology determines the net cost of the fire suppression system: the cost (a function of system size and weight) minus the cost savings (a function of extinguishant effectiveness and aircraft saved). An example for protecting the engine nacelles of an actual cargo aircraft shows how to incorporate into quantitative terms the contributions of the various cost factors and fire suppressant performance data being developed under the NGP. In this particular example, the value of a Halon 1301 system was compared to that of a HFC-125 system of equal performance. The latter system is slightly more expensive, but each represents only about 0.2 % of the life cycle cost of the aircraft. Either system would save the DoD about five times the system cost. Additional examples for engine nacelle and dry bay fire protection are nearly complete.

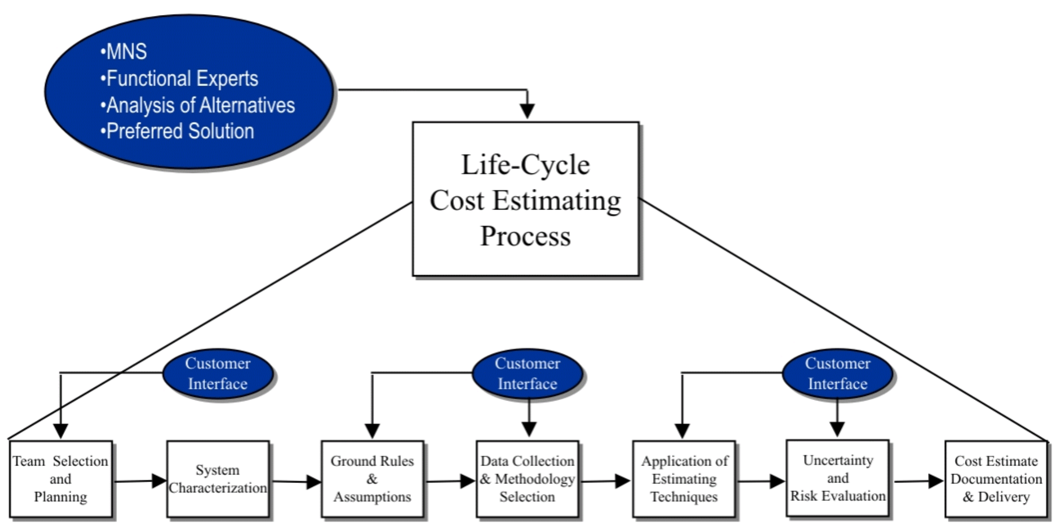

Figure II-15. Life-Cycle Cost Estimating Process.

Air Emission Reduction

Complying with the conformity requirements of the Clean Air Act is a challenge for the military when fielding new high performance aircraft and ships powered by gas turbine engines. High performance means higher engine operating temperatures, which generates higher levels of Nitrogen Oxide (NO_x) and volatile organic compounds (VOC) emissions. Collectively, military aircraft account for about 600 million pounds of VOCs per year and 190 million pounds of NOx per year. In a project entitled **Trapped Vortex Combustor for Jet Engines (PP-1042),** a research team from the Air Force Research Laboratory (AFRL) focused on the modeling and laboratory studies to establish design rules for trapped vortex combustors for military aircraft, ship, and ground power gas turbine engine applications. The project has demonstrated the low emissions and high performance characteristics of the trapped vortex combustor (TVC) designs at realistic high pressure, high temperature operating conditions.

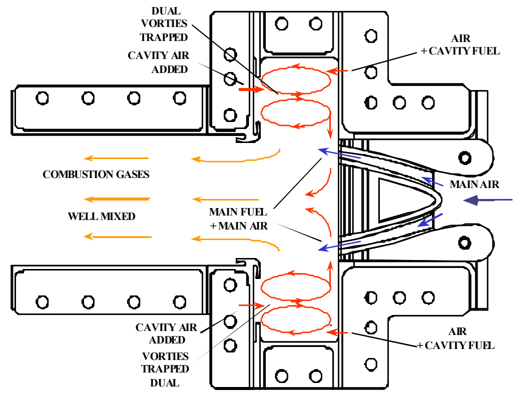

Figure II-16. The Trapped Vortex Combustor.

The research team has successfully demonstrated that a TVC, as represented in Figure II-16, could reduce emissions of both NO_x and VOCs by about 50% to 60% for aircraft and ship turbines, respectively, compared to current technology systems along with the operational characteristics improving dramatically. This technology successfully has transitioned to the Integrated High Performance Turbine Engine Technology Program and to ESTCP. The Naval Air Systems Command is leading a joint government/industry team to design and test an engine quality TVC for the engine that is used in the Navy F-18E/F fighter.

Elimination of Chromium and Cadmium

The DoD and DOE have committed to replace chromium (Cr)-based metal finishing in present and next generation systems. However, broadly applicable Cr-free coating systems do not currently exist. Consequently, there is a need to develop a better understanding of incumbent technologies based on the use of chromates so that they might be effectively replaced. The objective of a SERDP-funded research program, **Critical Factors for the Transition from Chromate to Chromate-free Corrosion Protection (PP-1119)**, is to acquire that fundamental understanding with a specific focus on corrosion protection of aluminum alloys.

Detailed studies in the formation of chromate conversion coatings established that coatings grow in two distinct stages with each contributing in a different way to coating corrosion protection. Supplemental agents in the coating bath that activate the surface and accelerate the process actually have a pronounced effect on subsequent corrosion protection characteristics. The concept of activating and accelerating substances may be very important in formulation of Cr-free coatings. Chromium corrosion coatings (CCC) are extremely sensitive to age, heat, and relative humidity as all of these factors affect coating dehydration. As a coating dehydrates, it loses corrosion protection, loses self-healing ability, and becomes less receptive to painting. The structural transformations induced by dehydration lead to these losses in performance. Figure II-17 illustrates the evolution of shrinkage cracking in a CCC due to dehydration in an environmental scanning electron microscope (ESEM). Clearly, avoiding this phenomenon is desirable in new coating systems. This research program also has teamed with researchers involved in the Air Force Office of Scientific Research (AFORS)-sponsored Multi University Research Initiative (MURI) on chromate corrosion protection to understand the effect of chromates and conversion coatings on inhibition of the cathodic portion of corrosion cell reactions. Coating aging studies have revealed how age decreases the ability to suppress this important corrosion reaction. These findings suggest ways in which new coatings might be made with corrosion protection exceeding that of chromates.

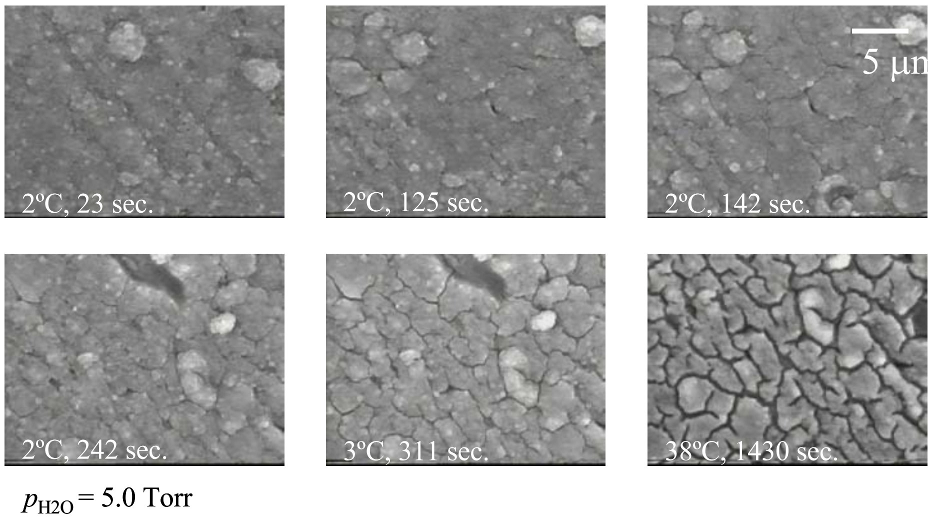

Figure II-17. Crack Formation during Drying as Observed by ESEM. Sample Temperature and Cumulative Exposure Time Are Indicated.

Reduction of Hazardous Materials/Solid Waste

The DoD has numerous high performance weapon platforms that require stringent monitoring of the structural integrity of the platforms owing to these structures low tolerance for corrosion and/or cracks. The need to inspect the substrates of these platforms for corrosion, fatigue cracks, and other operationally induced damage is very time consuming and costly, often necessitating the removal and subsequent replacement of the coating system, not to mention the handling of the hazardous wastes associated with these materials and processes. The paint, stripping, and repainting process generates significant and costly pollutant streams such as VOCs and hazardous air pollutants (HAP). Environmental regulations are limiting emissions of VOCs and HAPs, and DoD efforts to attain compliance have identified removal and reapplication of coatings as major contributors to the emissions problems at DoD facilities. Developing realistic and practical nondestructive inspection technologies for "inspection-through-paint" are considered to be a means by which the DoD can extend the service life of coatings systems, extend the life of aging weapons systems, meet the increasingly stringent environmental requirements, and increase operational capability. Two SERDP-funded projects made significant advancements in this important area in FY 2001.

Non-Destructive Testing of Corrosion Under Coatings (PP-1137) is developing non-destructive techniques to eliminate the need to remove otherwise functional coatings. In order to increase the life cycle of coatings and hence minimize coating removal and the associated wastes generated from stripping operations, it is required to have a technique that will reliably determine if corrosion or other potential structural defects are present under coatings. This requires a technique the will detect corrosion and other structural defects such as fatigue cracks with high fidelity under the applicable coatings.

A number of potentially viable non-destructive inspection techniques have been shown to have significant merit. Project accomplishments include evaluations of infra-red (IR) camera techniques for adaptation to the Wide-Area Spectral Imaging (WASI) concept, including in-house and commercial IR camera systems. The ability to see through thick organic coatings and detect corrosion, pitting, and fatigue cracks has been demonstrated with high clarity. Other viable techniques under investigation include Localized Impedance Spectroscopy, Conventional Volta Potential Measures with the Kelvin Probe, and Volta Potential Measurements in air. These techniques also have demonstrated that corrosion could be clearly detected under paint. Particular significant project accomplishments include the demonstrated ability of the IR technique to see fatigue cracks of down to 0.030 of an inch in length emanating from fastener holes, as well as corrosion pits on the order of 0.001 inches in diameter under standard military and commercial aircraft coatings. Additionally, coated aircraft fasteners with part numbers located on their heads could be clearly read without the need to remove coatings, giving the IR technique the ability to check that correct structural fastener has been installed either in rework operations or by the original manufacturer (See Figure II-18).

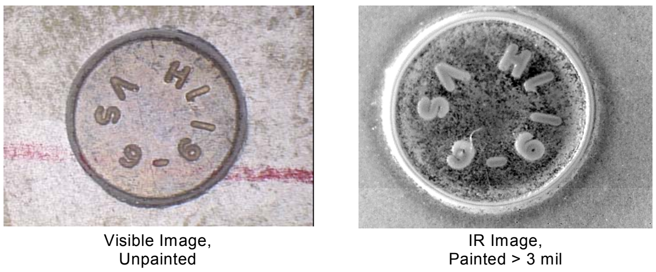

Figure II-18. Detail of Fastener Heads Using a 25 mm Lens and Broad Band Spectral Filter.

The other project, **Development of Innovative Nondestructive Evaluation Technologies for the Inspection of Cracking and Corrosion Under Coatings (PP-1134),** developed and evaluated three different innovative nondestructive evaluation technologies for the detection of fatigue cracks and corrosion hidden under paint. The project was led by a scientific team from the Naval Surface Warfare Center Carderock Division (NSWCCD) and the Naval Air Warfare Center Aircraft Division (NAWCAD) with participation from scientists within private industry and academia (Imperium, Inc., Wayne State University, Thermal Wave Imaging, Inc., Texas Research Institute/ Austin, and Colorado State University). The three technologies investigated included real-time ultrasound imaging, thermal imaging, and near-field microwave imaging. These technologies were selected and developed for their potential to inspect areas rather than points (this translates into efficient inspection scan rates), portability on the job site, overall projected economy to implement, and relative technology maturity.

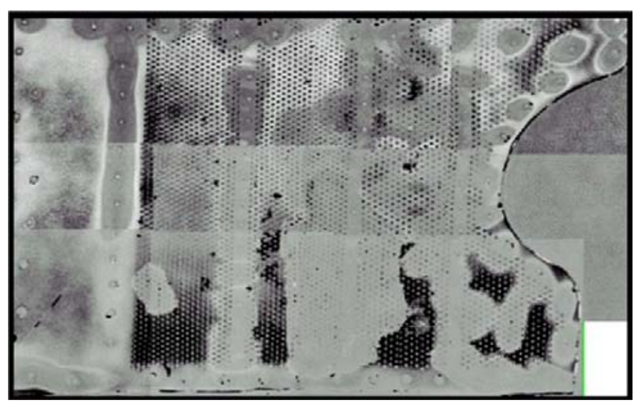

Figure II-19. Large Composite Thermographic Image of F-18 Intake Panel Created from 8 Smaller Individual Images.

Of the three innovative nondestructive technologies developed and evaluated during the course of the SERDP program, the pulse thermography system, and the real-time ultrasound imaging showed the most promise for transition to the field (see Figures II-19 and II-20, respectively). The through-transmission approach to real-time ultrasound imaging has received considerable attention from the aerospace industry. Boeing/Vertol has accepted delivery of a through transmission unit to inspect composite components on their production line. The pulse thermography system also is transitioning into the field. Navy Depot Cherry Point, NC, has an older pulse thermography system that currently is used for limited applications. The system developed under the SERDP program will expand these applications as a result of its greater sensitivity and increased portability. Other achievements under this program include the publication of eight papers, the submission of four reports, and the delivery of nine technical presentations at national and international conferences. In addition, Imperium, Inc., and NAWCAD have made an application for a patent based on the oblique angle beam real-time ultrasound imaging system.

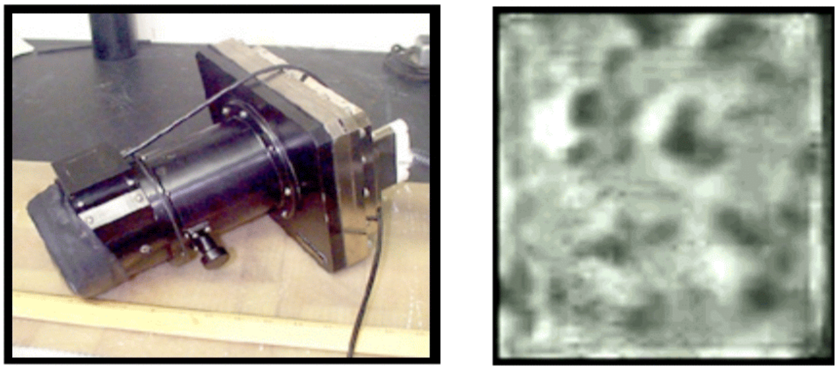

Figure II-20. Photograph of Acoustocam Real-Time Ultrasonic Imaging Camera and Image of Corrosion Pits (1 mm Diameter) Acquired with the Camera while Looking at the Front Surface of a Sample through Paint.

UXO Accomplishments

Use of ranges and munitions are an integral part of maintaining DoD's mission readiness. There is increased concern from the public and regulatory agencies regarding environmental and safety concerns with expanded munitions. Military training, exercises and weapons testing spanning many decades has resulted in unexploded ordnance contamination of significant land areas. Potential areas containing UXO has grown to include active military sites and land transferred for private use, such as Base Realignment and Closure (BRAC) sites and Formerly Used Defense Sites (FUDS). Technologies are required to characterize adequately sites containing UXO. The most important metrics are high detection rates and low false alarm rates (i.e., the frequency of declaring a UXO object present when none is there). Cleanup delays and excessive costs are often a result of high false alarm rates.

Figure II-21. Ordnance, Scrap and Natural Items.

Funded efforts in FY 2001 included the detection and classification of UXO using electromagnetic induction (EMI), magnetometer, radar, and seismic sensors. Often, UXO is co-mingled with extensive surface and subsurface clutter yielding overlapping sensor signatures (see Figure II-21). One such SERDP-funded project team from Duke University performing **Statistical Signal Processing with Physics-Based Models: Multi-Sensor UXO Detection and Identification (UX-1123)** has developed phenomenological models for EMI, magnetometer, and radar sensors. Since its initiation as an FY 1999 New Start, this project has sought to delineate those phenomenological features that most discriminate UXO targets from anthropic clutter (see Figure II-22). The project was chosen for the FY 2000 SERDP Cleanup Project of the Year Award. Over the last two years, the Duke team has developed models that accurately predict the response of EMI and magnetometer sensors to the presence of UXO and clutter objects.

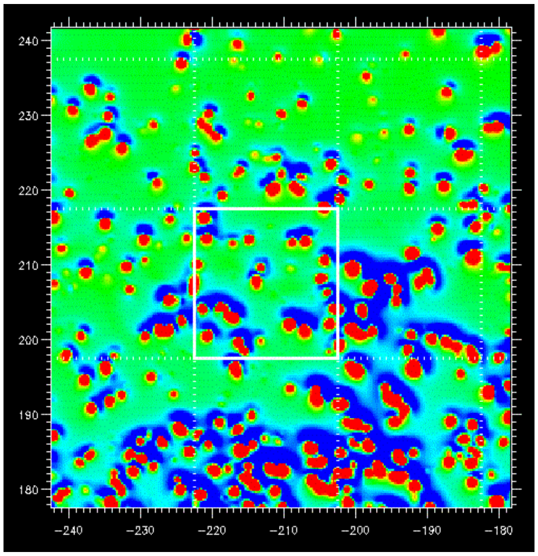

Figure II-22. Red Zones in this JPG(V) Dataset Identify High Probability UXO Targets.

FY 2001 work focused on phenomenological modeling of wave propogation and scattering for ultra-wideband radar, magnetometer, and EMI sensors. This included development and training of improved signal processing algorithms using data collected during the Jefferson Proving Ground (IV,V) experiments. These models have been used to develop advanced signal processing algorithms that have successfully been proven to reduce false alarm rates and increase the probability of detection.

Although this project ends in FY 2001, the research will be leveraged and extended in the Duke University FY 2002 New Start project, **Signal Processing and Modeling for UXO Detection and Discrimination in Highly Contaminated Sites (UX-1281)**. While clearly building off the successes under UX-1123, the focus of this new research is to (1) develop new physics-based signal processing approaches for discrimination of multiple UXO and clutter items co-existing within a sensor signal, and (2) understand the types of scenarios where clutter and UXO density is too high to perform reliable classification. Phenomenological models developed in FY 2001 will be used to train the statistical algorithms and generate a database of signals for testing of the algorithms to be developed under the FY 2002 New Start, **UX-1281.**

In FY 2001 SERDP also identified the need to pursue new efforts in the characterization of UXO-contaminated sites. However, in many cases, the actual contamination is concentrated on subsections of the potentially contaminated land, such as targeting areas. To appropriately direct detailed geophysical surveys, SERDP identified the goal of developing a sampling technique whereby a fraction of the site is initially investigated to identify clean and contaminated areas. This technique would be an improvement over the current sampling approach "SiteStats/ GridStats" that was developed in the early 1990s based on the available survey technologies at that time.

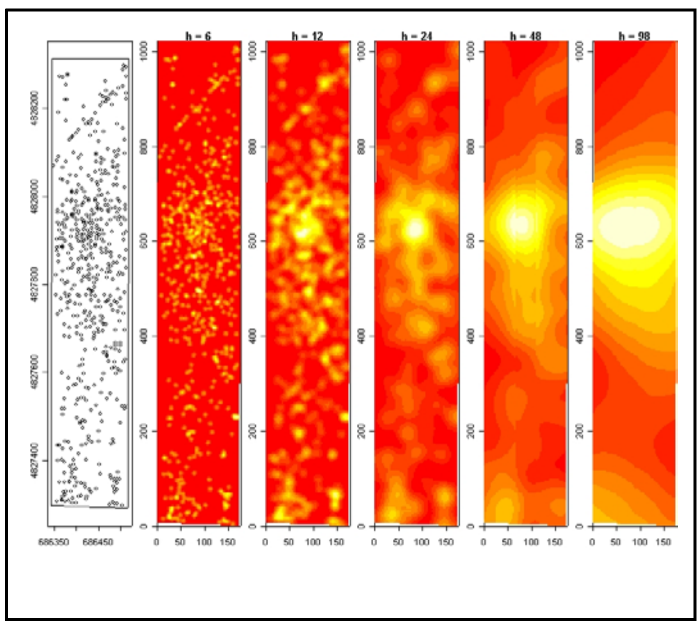

Figure II-23. The Interpretation of Field Scale Data (on Far Left) Collected at UXO-Contaminated Sites Allows for Distinguishing Areas of High Contamination within Larger Sites.

The objective of this initiative was to develop scientifically sound sampling procedures that can exploit modern geophysical surveying techniques to characterize sites potentially contaminated with UXO. Statistically valid sampling approaches are needed for the cost-effective investigation of UXO-contaminated sites. The footprint required for detailed geophysical surveys can be reduced if sub-sampling procedures can distinguish, with high confidence, boundaries of contamination within larger sites (see Figure II-23). Expected results from this work will provide the valuable data necessary to evaluate the scientific validity and to predict the cost savings and potential risks of the proposed sampling procedure, as compared to currently used techniques.

III. PROGRAM DESCRIPTION

General

The planning and management of individual projects are fundamental to SERDP's success in technology research and development. This section describes each of the SERDP Thrust Area Programs and how the projects respond to DoD needs and requirements. Topics include the goals of each Thrust Area, the environmental and operational drivers directing the needs for new and improved technologies, the major areas of research and development (R&D) within each Thrust Area, and the planned initiatives. Each FY 2001 and FY 2002 project is listed according to subthrust categorization and completion status.

The SERDP Program contains the following five Thrust Areas: Cleanup, Compliance, Conservation, Pollution Prevention, and the newly established Unexploded Ordnance (UXO). Each year the Executive Director, with the assistance of the Executive Working Group (EWG) and the Scientific Advisory Board (SAB), determines the funding balance among the Thrust Areas. Figure III-1 illustrates the distribution of funds to specific Thrust Areas for FY 2001 and FY 2002.

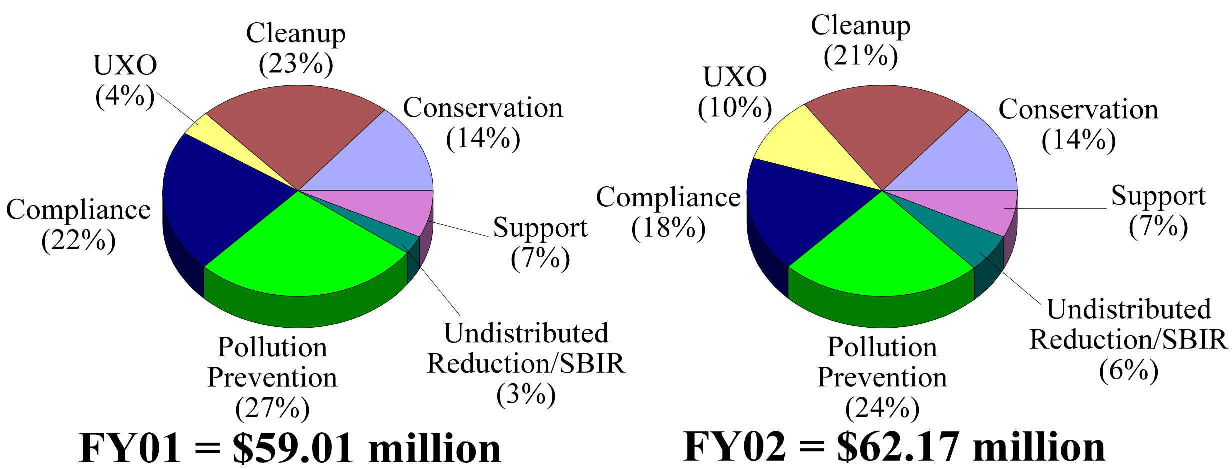

Figure III-1. Distribution of Total SERDP Funding, FY 2001 and FY 2002.

Program Development

SERDP PROJECTS FY 2001	
126	Total projects
44	Completed projects
FY 2002	
131	Total projects
49	New Start projects*

* Does not include projects to be funded under the FY 2002 Supplemental Solicitation.

SERDP funds environmental research and development through a competitive process in accordance with the established Congressional direction and is further guided by policies provided by the SERDP Council. There are usually two solicitations annually. One is the major, or core, solicitation and provides funding in various amounts for multi-year projects. The other is the SERDP Exploratory Development, or SEED, program designed to provide initial funding for high-risk, high-payoff projects. SEED projects are limited to a one-year time period and a maximum of $100,000 in funding.

Because both government and private sector parties may compete for SERDP funds, there are two announcements for each solicitation: (1) a Call For Proposals to the Federal sector and

(2) a Broad Agency Announcement (BAA) for the private sector. In the FY 2002 Federal Calls For Proposals, participating organizations and their laboratories were asked to solicit proposals that responded to the Statements of Need (SONs). Each Federal organization conducted its own internal down-select procedure and forwarded its best proposals to SERDP for consideration. The BAAs requested direct submission of proposals in response to the same SONs from non-Federal participants in industry, non-profit entities, and academia. Both the core and SEED BAA solicitations appeared in the Commerce Business Daily.

Each year, a peer review panel is used in the core solicitation to assist in the selection of Federal and non-Federal proposals. Following the peer reviewers' evaluation of technical merit and personnel, those proposals that were recommended by the peer review panels were forwarded to SERDP's multi-agency Technology Thrust Area Working Groups (TTAWG) who were tasked with reviewing both the Federal and non-Federal submissions of both solicitations for all evaluation criteria. All proposals recommended by the TTAWGs and approved by the Executive Director were briefed to the SERDP SAB prior to recommending their approval to the SERDP Council. Titles of these projects may be found in the lists of FY 2002 New Start projects within each Thrust Area description subsection, and summaries of each new project are located in Appendices A through E.

In addition to the annual solicitation, in FY 2001, SERDP conducted three "out-of-cycle" solicitations. Two special solicitations were issued early in FY 2001 for proposals as a result of additional funds appropriated by Congress. The first solicitation requested proposals against three SONs in the area of Live Fire Pollutants to address energetics contamination on active testing and training ranges. The second solicitation requested proposals in response to one SON that focused on environmental exposures to perchlorate, a component of solid rocket propellants. Finally, late in FY 2001, SERDP received an increase in the amended FY 2002 President's Budget Request (PBR) requiring a third solicitation that focused on UXO and other environmental issues related to training and testing ranges. Because the schedule for selecting these proposals carried over into FY 2002, new FY 2002 projects resulting from this supplemental solicitation are not included in this report. Detailed descriptions of all SONs can be found in Appendix F.

CLEANUP

Introduction

The Department of Defense (DoD) and the Department of Energy (DOE) must protect human health and the environment, reduce remediation costs, and provide timely cleanup. Cleanup goals for the DoD are:

- To attend to imminent threats to public health and safety
- To remediate all defense sites having a significant public health risk as quickly as feasible within the constraints of available resources
- To expedite transfer of base realignment and closure (BRAC) sites and formerly used defense sites (FUDS) to future owners

The DoD and DOE have a legal obligation to meet Federal, state, and local environmental protection and public health regulations. Both organizations own and operate thousands of installations, ranging from training bases to industrial production facilities. DoD's environmental restoration program must address more than 27,000 sites at more than 8,500 installations. Due to the large number of DoD and DOE sites and installations, many significant challenges exist and must be addressed. These challenges include chlorinated solvents, also known as Dense Non-Aqueous Phase Liquids (DNAPLs), as well as recently emerging issues such as perchlorate, metals, and energetic compounds (TNT, DNT, RDX, and HMX) in groundwater.

Restoration funding levels over the past nine fiscal years have averaged more than $2 billion per year and are projected to continue just below that level into the future. Commensurate R&D funding is necessary to ensure these challenges are met head on.

Experience with past remediation technology development has demonstrated a significant return on investment. Defense environmental managers require cost-effective and timely remediation capabilities that focus on assessment, characterization, and treatment. Within the Cleanup Technology Thrust Area, the primary environmental concerns are that the DoD:

- Implement timely, effective, and affordable methods for site characterization
- Ensure the use of effective, affordable remediation technologies
- Comply with various Federal, state, and local regulations for site remediation

These concerns are addressed by the Cleanup subthrusts and research areas as depicted in Figure III-2.

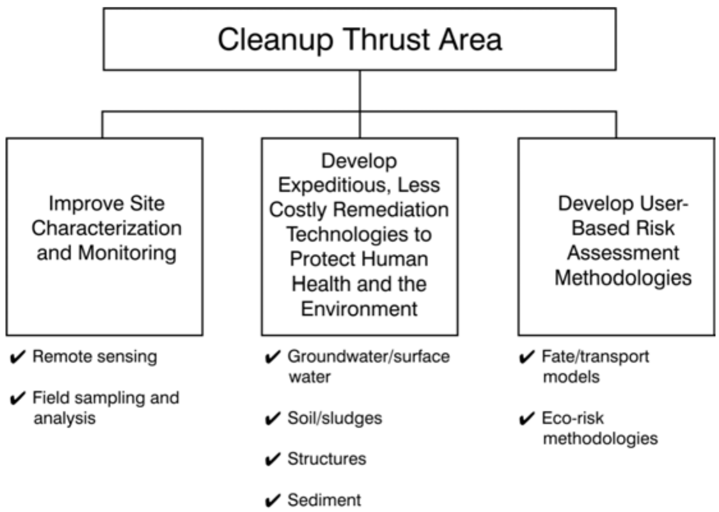

Figure III-2. Cleanup Taxonomy.

While many defense cleanup situations will require that technologies be identified in the near-term, additional research on the scientific fundamentals of contaminant behavior and remediation techniques has the potential to provide the highest return on investment. Congress appropriated funds in FY 2001 specifically to conduct efforts investigating environmental toxicology and remediation of energetics.

Principal Driving Requirements

The first subthrust area in Cleanup, **Improve Site Characterization and Monitoring**, seeks to develop better site investigation technology for locating and characterizing wastes. Identifying and characterizing sites contaminated with chlorinated solvents is a significant issue to the DoD. Chlorinated solvents represent a class of contaminants that are detected at more DoD sites than any other contaminant group. Chlorinated solvents, predominantly perchloroethylene and trichloroethylene, have been used in massive quantities over the last four decades. Release of these liquids to the environment accounts for a significant portion of the contaminated sites requiring cleanup. These contaminants have migrated through the subsurface and entered groundwater at more than 50 percent of the contaminated DoD sites. There is a comparable degree of contamination at DOE and private industry Superfund sites. Estimated annual costs exceed $500,000 for containing and monitoring a single DNAPL plume. Novel technologies to detect and characterize these plumes will significantly reduce these costs.

The second subthrust area in Cleanup, **Develop Expeditious, Less Costly Remediation Technologies to Protect Human Health and the Environment**, focuses on improved remediation of contamination in soils, groundwater, and sediments. Once contaminants reach the groundwater, they often are very mobile and can readily affect off-base receptors. Therefore, this subthrust is directed primarily at developing innovative technologies to address groundwater remediation more effectively. Current groundwater treatment strategies typically employ pump-and-treat technologies which are expensive to operate and are very slow to achieve lasting cleanup. Major limitations to the use of conventional pump-and-treat technology relate to difficulties in extracting contaminants from source areas where non-aqueous phase liquids (NAPLs) exist. In the area of energetic contamination, DoD is concerned with nitrated compounds that are widespread contaminants at DoD sites and have been identified at munition training ranges and production facilities. Trinitrotoulene (TNT) is the primary contaminant at these sites, along with dinitrotoluene (DNT), and other nitro substituted explosives (e.g., RDX and HMX). Current approaches used for site remediation typically involve excavation of contaminated soils, followed by incineration or composting, and pump and treat for contaminated groundwater. Because of past DoD and industrial activities, sediments at numerous sites also have some level of impact from anthropogenic (man made) compounds. The DoD must assess and manage contaminated sediments to conduct dredging, base closure, or to cleanup contaminated "hot spots." Remediation of contaminated sediments has proved to be very costly with current methods and environmentally risky. New and innovative technologies to treat and remediate contaminated sediments are needed to drive costs down and avoid potential impacts to surrounding areas.

The third subthrust area in Cleanup, **Develop User-Based Risk Assessment Methodologies**, involves identifying and evaluating the risk to human health and ecosystems on DoD installations potentially requiring environmental remediation. These include: (1) distinguishing those sites that pose significant environmental risks from those that pose little risk; (2) prioritizing contaminated sites by the degree of risk posed; (3) quantifying the risks at each site; and (4) developing appropriate remedial actions and cleanup goals. Development of improved techniques for risk assessment, which provides a logical framework for making such decisions, is a DoD priority. The effectiveness of existing risk assessment methods will be expanded by research directed at problems particularly evident at DoD installations.

Leveraging with other defense science and technology programs and industry, the Cleanup Technology Thrust Area focuses on the following R&D objectives:

- Develop investigation methods and technologies that are capable of locating and characterizing wastes in a timely and cost effective manner with the highest level of quality control

- Develop innovative, compliant technologies that reduce remediation costs for sites containing explosives, propellants, petroleum hydrocarbons, solvents, heavy metals, and other organic/inorganic contaminants

- Facilitate transfer of cleanup technologies to field use. This includes, but is not limited to encouraging the use of the National Environmental Technology Test Sites (NETTS) (see Appendix A for NETTS summaries)

- Develop cost-effective methods and tools to determine fate, transport, and effects of significant defense-related contaminants

- Develop risk-based modeling and simulation methods for hazard assessment and establishing cleanup priorities and scientifically defensible cleanup levels

- Develop scientifically defensible environmentally acceptable endpoints (EAEs) for DoD chemicals of concern, including chlorinated organics, explosive compounds, and heavy metals, to facilitate risk-based cleanups at DoD sites

- Develop reliable and cost effective means to identify, assess, and clean lands and underwater areas (inland, estuarian, and marine) contaminated with unexploded ordnance

Cleanup Program

CLEANUP

FY 2001	
44	Total projects
16	Completed projects

FY 2002	
38	Total projects
10	New Start projects*

* Does not include projects to be funded under the FY 2002 Supplemental Solicitation.

For FY 2001, the Cleanup Technology Thrust Area received approximately 23 percent of the SERDP budget. SERDP conducted four separate solicitations that requested project proposals in the Cleanup Thrust Area. In addition to the annual solicitation issued in FY 2000 for funding in FY 2001, Congressional actions initiated two special solicitations for FY 2001 funding that involved only the Cleanup Thrust Area. The first solicitation issued three SONs in the area of Live Fire Pollutants addressing energetics contamination on military ranges and the second solicitation issued one SON addressing environmental exposure to perchlorate. Projects resulting from these solicitations are included in this report. Late in FY 2001, the supplemental solicitation (mentioned previously) for FY 2002 funding issued one SON in the Cleanup Thrust Area. Due to its issuance in late FY 2001, new projects from this solicitation could not be included in this report. The five SONs from the two special and one supplemental solicitation are briefly described below. All SONs are further described in detail in Appendix F.

In response to environmental issues regarding the Massachusetts Military Reservation and other training and testing ranges, FY 2001 funds were appropriated to investigate the impacts of Live Fire Pollutants. The objective of the first FY 2001 Live Fire SON, entitled **Screening Level Assessment of Energetics Contamination**, is to seek fundamental or applied studies to develop innovative, rapid screening technologies to detect and delineate land areas with soils containing contaminants associated with live fire training activities including energetic compounds (RDX, HMX, TNT, DNT), propellants, and their byproducts. This SON does not solicit technologies for the detection of unexploded ordnance, but rather for detection of energetic chemical constituents in soil. It is a second FY 2001 Live Fire SON, entitled **Containment of Source Zone Energetic Contamination**, the objective is to develop innovative technologies to prevent migration of surface and near surface (< 1 foot below ground surface) soil contamination by energetic materials (RDX, HMX, TNT, and DNT) that may act as a source zone for groundwater contamination on DOD testing and training ranges. A third SON, entitled **Containment and Treatment of Energetic Compounds in Groundwater**, seeks to develop innovative in-situ technologies to contain and/or treat energetic compounds (RDX, HMX, TNT, and DNT) in groundwater. Of primary interest are large groundwater plumes associated with sources on DoD live fire ranges.

The objective of the FY 2001 Perchlorate SON, entitled **Impacts of Environmental Exposures to Ammonium Perchlorate on Fish, Amphibians and Small Rodents**, is to examine the impact of environmental exposures of ammonium perchlorate on avian species, small rodents, amphibians and fish. This research should provide information for identified data gaps regarding perchlorate and its potential impacts on the natural environment. Information obtained from this research will support in establishing standards that are protective not only for humans but for the environment as a whole.

In addition to those FY 2002 SONs listed in last year's report, the Supplemental Solicitation SON entitled **Containment/Treatment of Energetic Material Releases on Testing and Training Ranges** seeks to develop innovative technologies capable of sustained prevention of migration of surface and near surface soil contamination by energetic materials (RDX, HMX, TNT, and DNT) that may act as a source of groundwater contamination on DoD testing and training ranges. Technologies should be applicable to large, potentially vegetated areas and should be directed to long-term control of energetic materials either through repeated applications of relatively inexpensive and rapidly deployable technologies or through self-sustaining treatment technologies such as phytoremediation.

The following list reflects projects completed in FY 2001 and projects continuing into FY 2002. Also included are titles of projects that begin in FY 2002. Complete descriptions of all of the projects for FY 2001 and FY 2002 can be found in Appendix A - Cleanup Project Summaries.

Subthrust: *Improve Site Characterization and Monitoring* Page

FY 2001 Completed Projects

FY 2002 Continuing Projects

FY 2002 New Start Projects

Subthrust: *Develop Expeditious, Less Costly Remediation Technology*

FY 2001 Completed Projects

FY 2002 Continuing Projects

FY 2002 New Start Projects

Subthrust: *Develop Risk Assessment Methodologies*

FY 2001 Completed Projects

FY 2003 Cleanup Initiatives

The remediation of chlorinated solvents is a major research priority in the Cleanup Thrust Area. To this end, in FY 2003, the SERDP Cleanup area will solicit proposals to research three chlorinates solvent topics. Statement of Need (SON), **DNAPL Source Zone Delineation and Characterization**, has been issued. Through this SON, SERDP looks to develop technologies and approaches to delineate and characterize chlorinated solvent DNAPL source zones. Specific objectives include: (1) develop better tools and procedures to delineate and characterize DNAPL source zones, and (2) develop protocols and guidance for cost-effectively characterizing source zones using existing and/or new technologies to aid in selection and design of remediation options. Research on improved site characterization techniques should lead to methods that provide the types of information needed for remediation system selection and design. Site characterization often constitutes a large portion of the overall budget and time of a remedial effort. A practical assessment of critical data needs to complete system design is essential when developing site characterization technologies. The contaminants of concern include tetrachloroethene (PCE), trichloroethene (TCE), and their breakdown products. Results from this research will aid in developing a better understanding of the nature and extent of DNAPL source zones and in creating a realistic approach to source zone characterization recognizing the inherent limitations. Research and development activities at laboratory-, bench-, and field-scale will be considered, but work does not necessarily have to culminate in a field-scale effort.

Another DNAPL-related proposed area of new research is entitled, **Diagnostic Procedures to Evaluate Remediation Performance at Chlorinated Solvent-Contaminated Sites**. The objective of this SON is to seek fundamental or applied studies to (1) develop diagnostic procedures to evaluate the performance of chlorinated solvent source zone and/or groundwater plume in-situ remedial technologies and (2) develop better technical guidance on using diagnostic procedures to improve our ability to determine technology-limited remedial endpoints at chlorinated solvent-contaminated sites. Results from this research will aid in developing real-time, cost-effective techniques to evaluate the effectiveness of remedial approaches and will assist in developing better technical guidance on using diagnostic procedures to improve our ability to quantify technology-limited remedial endpoints at chlorinated solvent-contaminated sites.

A third DNAPL-related proposed area of new research is entitled, **Assessment of Long-Term Sustainability of Monitored Natural Attenuation of Chlorinated Solvents**. The objective of this SON is to seek applied studies to develop a better understanding of the long-term sustainability of natural attenuation of chlorinated solvents such as tetrachloroethene (PCE) and trichloroethene (TCE) and their breakdown products (dichloroethene [DCE] and vinyl chloride [VC]). Guidance on appropriate characterization methods and development of accurate predictive models are needed as well as effective evaluation and assessment of all natural attenuation processes that might occur, including reductive dehalogenation, aerobic biodegradation, dilution, dispersion, sorption, volatilization, and abiotic degradation. Results from this work will provide the practical understanding of the long-term sustainability of natural attenuation of chlorinated aliphatic hydrocarbons under various field conditions. This understanding will allow engineers to more accurately predict the time required to attain environmentally acceptable endpoints through natural attenuation and their sustainability.

The last core FY 2003 proposed area of new research will investigate, **In-Situ Sequestration Enhancement and Engineered Bioavailability Reduction of Metals in Soils**. The objective of this SON is to seek fundamental and applied studies to develop a better understanding of the enhancement of in-situ sequestration and/or engineered reduction of metals bioavailability in soils. This SON seeks to increase the knowledge base regarding the mechanisms by which different soil amendments or other approaches alter the form of metals in soil and the resulting impacts on bioavailability. Mechanisms may vary by soil type, soil amendment, and/or remedial approach, but may include precipitation, humification, sorption, ion exchange, chelation, and redox transformations. Chemical alterations of the metals should be long-lasting, preferably permanent. The proposed work should lead to development of a greater understanding of control of sequestration and/or reduced bioavailability processes that will result in long-term stability of DoD metals of concern in soils.

COMPLIANCE

Introduction

In the United States, the DoD must comply with Federal environmental protection laws such as the Clean Water Act (CWA), the Clean Air Act and Amendments (CAAA), and the Resource Conservation and Recovery Act (RCRA), as well as state and local regulations. These laws result in specific requirements for the treatment of emissions and disposal of wastes generated during DoD operations, including those generated by vehicles, aircrafts, and vessels, as well as from training exercises involving the firing of munitions. At the international level, the International Maritime Organization's Marine Pollution Convention (MARPOL) Annexes (to which the United States subscribes) may restrict or prohibit DoD operations in international waters and MARPOL Special Areas unless vessels meet international environmental statutes. In addition, countries that host DoD facilities are implementing and enforcing compliance with regulations and standards that may restrict or prohibit DoD operations in foreign ports and bases.

Together, these requirements affect numerous defense activities and assets both at home and abroad, including combat testing and training; operational installations; ordnance and weapons manufacturing and disposal; and combat vehicles, ships, and aircraft operations. As a result, DoD is projected to spend approximately $1.7 billion annually for environmental compliance over the next several fiscal years, requiring monitoring and treatment of emissions and wastes generated by military operations and training. New technologies must be developed to reduce this cost and enable the DoD to comply fully with increasingly stringent requirements while fulfilling its mission unencumbered by regulatory fines, restricted access or mobility, or negative public reactions. In addition, full compliance with environmental regulations is a critical step in DoD's initiative to achieving and maintaining sustainability.

Therefore, the mission of the Compliance Technology Thrust Area in SERDP is to research and develop new technologies to:

- Address current and future environmental compliance requirements of the DoD and DOE while maintaining military readiness

- Reduce the costs associated with these requirements

Compliance technologies are not to be directly related to site restoration but are related to meeting current and future environmental compliance requirements of DoD and DOE. They are applied, for example, to end-of-pipe and/or control recycling (i.e., waste that is reused for other than its original purpose), or investigations to assist the development of new regulations which often involve the fate and transport of defense-related air and wastewater discharges. Compliance technologies do not include elimination of waste streams through substitution or process modification which are included in the Pollution Prevention Thrust Area.

The primary concerns in this technology thrust area include deterioration or loss of operational capability and the high costs of regulatory compliance. These primary DoD environmental concerns reflect the need to:

- Better characterize wastes though improved measuring/monitoring technologies
- Develop effective treatment/recycling technologies for defense wastes and/or emissions
- Develop improved fate and transport prediction capabilities for emissions and/or discharges of specific compounds or contaminants

Each of these DoD user requirements respond to specific environmental regulations that have been developed under the CAAA, the CWA and amendments, and, for solid and hazardous wastes, the RCRA. Given the compliance requirements that result from these three major laws and their3 amendments, as well as related standards, SERDP addresses Compliance according to the five major subthrust areas related to affected environmental media shown in Figure III-3.

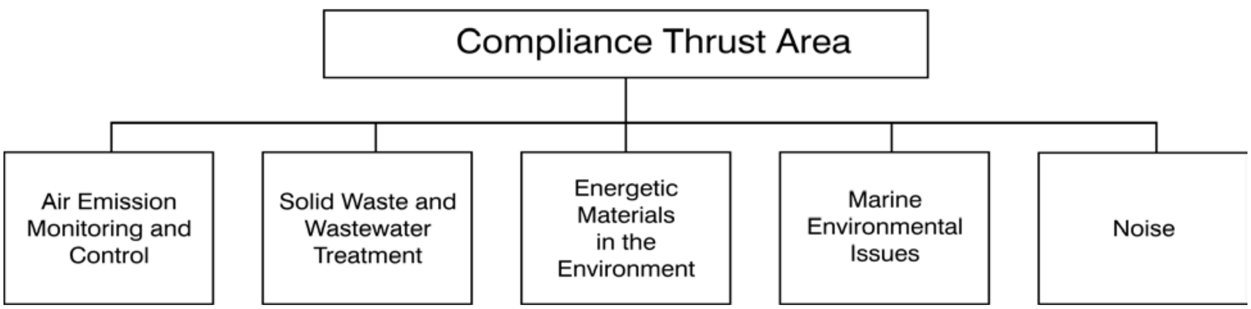

Figure III-3. Compliance Taxonomy.

SERDP's Compliance Technology Thrust Area investment is anticipated to remain level over the next five years, although this could change with the implementation of new environmental regulations. Congress appropriated funds in FY 2001 specifically to conduct efforts in support of health and safety training aspects related to persons undertaking remediation work, including the scrapping of Navy ships.

Principal Driving Requirements

For FY 2001, SERDP responded to requirements resulting from specific regulatory developments via investments in the five Compliance subthrusts. The **Air Emissions Monitoring and Control** subthrust addresses DoD's need to develop new and effective measuring/monitoring and treatment/control technologies for air emissions resulting from DoD activities. In the course of implementing the CAAA of 1990, a number of local air quality jurisdictions (many facing non-attainment status for one or more priority pollutants) have imposed local standards that are more stringent than national emissions standards. The employment of military-unique systems such as liquid-fuel rockets, military jet engines, and mobility equipment will require that DoD treat and control emissions of NOx, ultrafine particulate matter (PM), volatile organic compounds (VOC), and hazardous air pollutants (HAP) at DoD installations. One difficulty associated with monitoring and controlling these emissions is that they frequently are episodic or high-volume and low-concentration, such as jet engine test cells, painting, stripping, and cleaning operations. Existing CAAA regulations continue to test the limits of existing emissions monitoring and control technology which in some cases does not meet portability or detection limit requirements. Anticipated future requirements, such as the expanded National Emission Standards for Hazardous Air Pollutants (NESHAPs), will increase the number of production and maintenance processes that require continuous monitoring and control, thereby creating further technology needs and applications. Additionally, the generation of dust and resultant fugitive dust emissions via military activities is becoming an issue of growing concern due to encroachment around military ranges. Without new technology, the curtailment of missions, closing of facilities, and assessment of fines are real possibilities.

The **Solid Waste and Wastewater Treatment** subthrust addresses DoD's need to meet international environmental regulations limiting the disposal of solid waste and plastics at sea. To address this need, the Navy must develop compact, efficient equipment for the destruction of solid waste and sludges from waste water onboard DoD vessels. The CWA requirements also prohibit the discharge of untreated sewage (blackwater) by ships in navigable waters. Shipboard graywater is the product of hotel and commissary-type activities aboard U.S. Navy ships. Common sources of graywater are showers, sinks, and galley and scullery equipment. No graywater holding capacity has been required for U.S. Navy ships with the exception of operations within the Great Lakes. However, with anticipated tightening of global wastewater discharge regulations, DoD must develop technologies that are appropriate to control and treat combined shipboard graywater and blackwater (i.e., non-oily wastewater).

Within the **Energetic Materials in the Environment** subthrust, research and development is aimed at managing military ranges as a sustainable resource. This subthrust focuses on developing techniques to assess the potential for environmental impacts of residual energetic materials that may be found at military ranges as a result of the use of munitions. The research conducted under this subthrust is intended to contribute to the DoD's capacity to: (1) understand range environmental issues; (2) improve management of these critical resources; (3) assure the long-term viability of these key assets; and (4) facilitate compliance with current and proposed regulations. It supports the 1996 Defense Science Board (DSB) Report and Environmental Security Plan for test and training range sustainment. The disposal of the large stockpile of munitions and propellants by OB/OD is also addressed by this subthrust. Concerns have been raised about the impacts of OB/OD activities on the health of humans and ecosystems, severely restricting sometimes prohibiting, OB/OD. Additionally, the EPA is proposing TRI reporting requirements for munitions which will require new and innovative technologies to monitor and characterize emissions of TRI chemicals munitions firing. On a related issue, DoD needs to dispose of an increasing amount of metal scrap material produced by testing and training activities that use munitions and other energetic materials. These scrap materials may contain energetics residues that could pose a hazard to efforts for the recycling of this metal scrap.

The **Marine Environmental Issues** subthrust is focused on the scientific fundamentals of the fate and impact of copper and zinc from DoD sources in harbors and estuaries in order to develop a scientific basis for future approaches to copper and zinc regulations. Copper and zinc are two of the most ubiquitous contaminants found in many industrial and non-point source effluent, including discharges from DoD facilities, ships, and small craft into the marine environment and sediments disrupted during dredging operations. DoD sources of copper include storm water runoff, point sources, hull coatings, and discharges from DoD ships and facilities. Studies have shown that copper and zinc are highly toxic to some marine organisms. Copper and zinc discharges often exceed existing water quality criteria (WQC) or standards in the effluent and copper often exceeds WQC in the receiving systems. DoD needs to provide risk assessments that can identify the DoD sources of copper and zinc discharging into or present in harbors and/or estuaries and evaluate the risks to marine species from these metals. Examining the fate and impact of these metals has the long-term benefit of providing empirical evidence to support the development of more realistic scientifically-based water quality criteria and standards.

For the **Noise** subthrust, efforts are required to provide refined acoustic models for improved ability to accurate predict the resulting noise footprint and potential impact of DoD operations. They would assist environmental specialists in proposing mitigation techniques to site managers and operators. This would be particularly advantageous in regions where the impacts of such operations are dependent on the interaction of environmental conditions. Another objective is to create a fully validated models for high performance aircraft noise and other high intensity noise sources to provide a legally defensible characterization of DoD noise impacts.

Compliance Program

COMPLIANCE	
FY 2001	
21	Total projects
8	Completed projects
FY 2002	
26	Total projects
13	New Start projects*

* Does not include projects to be funded under the FY 2002 Supplemental Solicitation.

For FY 2001, Compliance received approximately 22 percent of the total SERDP budget. In FY 2001, SERDP conducted two solicitations that requested project proposals in the Compliance Thrust Area and supported 21 Compliance projects. Nine projects are listed under the Air Emissions Monitoring and Control subthrust, three of which address emissions treatment/reduction technologies and seven that develop measuring and monitoring technologies for dust and other air emissions. In the Marine Environmental Issues subthrust, three projects are evaluating the fate and transport of copper and zinc in the water column and in the sediments in estuarine environments. Of the six projects addressing Energetic Materials in the Environment, two focus on characterization and removal of energetics residue on range scrap, and four evaluate the fate and transport of energetic materials in soil and air including UXO casing corrosion. Two completed projects under the Solid Waste and Wastewater Treatment subthrust focused on thermal sludge treatment and biodegradation of oily wastewaters. One congressionally-directed project focuses on environmentally sound technologies for the scrapping of Navy ships.

The SERDP Compliance Thrust Area solicited proposals and approved twelve FY 2002 New Start projects that will focus on (1) emissions of trace air toxic compounds, especially persistent organic pollutants; (2) aqueous non-indigenous species related to ballast waters and ship hulls; (3) fate and environmental effects of the new energetic material known as CL-20; (4) military aircraft noise propagation; and (5) the impacts of land management on the fate and transport of energetics material. The latter two were submitted as supplemental solicitations after a mid-year budget increase.

Four new start projects were selected for funding in FY 2002 to address the fate and transport of air pollutants associated with DoD activities. These projects focus on the development of spatially-based emission rates, transport, transformation, and the development of predictive models. One of these projects is a one-year effort to conduct a sensitivity analysis for predicting air quality impacts. Marine environmental issues are being addressed by five new start projects that aim to characterize harmful non-indigenous species associated with ship ballast water and ship hulls. Three out of the five projects are one-year efforts. The fate and environmental effects of the new energetic material known as CL-20 are being evaluated in three new start projects. Proposal selection for the other two solicitations (i.e., military aircraft noise propagation; and the impacts of land management on the fate and transport of energetics material) will be completed in the second quarter of FY 2002.

Late in FY 2001, the supplemental solicitation (mentioned previously) with FY 2002 funding issued two SONs in the Compliance Thrust Area. Due to the late timeframe, new projects from this solicitation could not be included in this report. The two SONs from the supplemental solicitation are briefly described below. All SONs are further described in detail in Appendix F.

The objective of the first FY 2002 Supplemental Solicitation SON, entitled **Advanced Acoustic Models for Military Aircraft Noise Propagation and Impact Assessments,** is to provide an improved predictive capability to estimate noise propagation from military aircraft operations at military facilities and calculate the footprints used for determining the impact of noise emitted on local and regional communities. Proposed work will exploit advanced non-linear acoustic propagation science, enhance existing or develop new acoustic models, develop new 3-dimensional acoustic source directivity measuring techniques for both ground and airborne sources, validate the new acoustic models, and develop dynamic data visualization systems to aid impact assessments.

The objective of the second FY 2002 Supplemental Solicitation SON, entitled **Land Management Impacts on the Environmental Fate and Transport of Energetic Materials on DoD Test and Training Ranges,** is to investigate and assess the impact of land management practices on the environmental fate and transport of energetic materials that may be released due to live fire activities on DoD terrestrial test and training ranges. The land management actions of interest include activities such as burning, thinning, planting and seeding, or other restorative and mitigation measures used for range sustainability. The primary energetic compounds of interest are RDX, HMX, TNT, DNT and their breakdown products. The primary migration pathways of concern include surface run-off and subsurface migration/leaching to groundwater.

The following list reflects projects completed in FY 2001 and projects continuing into FY 2002. Also included are titles of projects that begin in FY 2002. Complete descriptions of all of the projects for FY 2001 and FY 2002 may be found on the pages referenced in Appendix B - Compliance Project Summaries.

Subthrust: *Air Emissions Monitoring and Control* **Page**

Subthrust: *Solid Waste and Wastewater Treatment*

Subthrust: *Energetic Materials in the Environment*

Subthrust: *Marine Environmental Issues*

Subthrust: *Noise*

Projects for this subthrust are planned in the FY 2002 supplemental solicitation but have not yet been selected as of the writing of this report.

FY 2003 Compliance Initiatives

FY 2003 Compliance Initiatives will respond to recently finalized as well as anticipated regulatory developments related to (1) DoD air emissions from off-road diesel vehicles and, (2) characterizing and monitoring non-point source runoff from military ranges and identifying their impacts to receiving water bodies.

State and Federal regulators are developing emissions inventories of NOx and PM2.5 which are needed for the development of State Implementation Plans to control emissions of these criteria air pollutants. The impact on DoD activities as a result of the promulgation of EPA regulations in non-attainment areas or for source-specific emission limits could be substantial. To proactively respond to this potential restriction to DoD operations, SERDP has issued a SON for FY 2003 entitled **Characterization of Off-Road Diesel Vehicle Emission of Criteria Air Pollutants**. The objective of this SON is to develop sampling methods and characterize emissions of criteria air pollutants from DoD-unique diesel engines, specifically from off-road diesel vehicles and diesel generators. The anticipated results of this work will provide accurate estimates of the DoD sources of these criteria air pollutants from off-road and stationary diesel engines.

The 1987 amendments to the Clean Water Act (CWA) and the 1990 Coastal Zone Act Reauthorization Amendments (CZARA) established a number of programs to address non-point source pollution. Section 319 of CWA amendments established the Non-point Source Management Program, which requires an assessment of the extent of non-point source water quality problems and the development and implementation of best management practices (BMPs) to prevent water runoff from becoming polluted, and where it is polluted, to reduce the amount that reaches streams, rivers, lakes and estuaries. The 1987 CWA amendments also require the identification of pollution-impaired surface water and the development of TMDLs that set the maximum amount of pollution a water body can receive without violating water quality standards. CZARA established goals to be achieved in controlling the addition of pollutants to out coastal waters and requires the development of coastal non-point source control programs. Through implementation of the CWA, it is the responsibility of DoD, to protect and restore the quality of public waters under their jurisdiction. To support this effort, SERDP has issued a SON for FY 2003 entitled **Characterizing and Monitoring Non-point Source Runoff from Military Ranges and Identifying Their Impacts to Receiving Water Bodies.** The objectives of this SON are to provide tools and/or data (1) to characterize and monitor non-point source runoff resulting from military activities on DoD training and testing ranges, and (2) to identify the impact of these sources on receiving waters.

Detailed descriptions of the FY 2003 Compliance Statements of Need may be found in Appendix F.

CONSERVATION

Introduction

DoD is a major user of land, sea, and air, and manages approximately 25 million acres of land on more than 425 major military installations. It is the third largest Federal land management department in the United States. DoD requires continued access to these lands, waterways, and airspace to maintain mission readiness. Land is needed for munitions testing, deployment of weapon systems, and combat training exercises. Marine and estuarine environments are needed to conduct training exercises, test vessels and submarine tracking equipment, evaluate missile weapon systems, and conduct shock trials on new ships. Airspace is needed to train pilots and test fighter planes and air-based weapon systems. The specific landscapes and unique natural features of the land, sea, and air space used by DoD are crucial to maintaining military readiness. Varied training regimens and differing climatic, topographic, hydrologic, and biological settings prepare troops to operate equipment and carry out operational plans under conditions that they may encounter in future conflicts. With a broad geographic distribution (largely domestic but some foreign), DoD lands represent a remarkably diverse collection of ecosystem and habitat types, including forests, grasslands, wetlands, and deserts. DoD's ability to conduct realistic training exercises and to test weapon systems and equipment cannot be ensured without responsible land stewardship and sensible management and conservation practices.

DoD must sustain the ability to train personnel and test weapons while maintaining the natural and cultural resources of the installations upon which it depends. It also must comply with legislation and regulations designed to protect these resources. By better understanding the environments in which they operate, the Department can improve its resource-use decisions to promote conservation and stewardship, while continuing to fulfill their primary missions. The DoD Conservation goal is to support the military mission by: (1) providing for sustained use of its land, sea, and air resources; (2) protecting valuable natural and cultural resources for future generations; (3) meeting all legal requirements; and (4) promoting compatible multiple uses of those resources.

Furthermore, military facilities face increasing demands as a result of base closures and realignments, new weapon systems and equipment requiring larger training ranges, additional regulatory constraints, and changes in tactics and doctrine. Training intensity on remaining installations will continue to rise, often preventing full recovery of vegetation and animal populations between training exercises. The U.S. Army alone has millions of acres of training and testing lands with significant land repair and maintenance costs. On-site and off-site environmental impacts, wildlife conservation issues, cultural resources concerns, and the need for training realism all dictate that natural resources must be maintained and enhanced on these installations. The tasks of balancing military land uses, complying with resource regulations, and assessing impacts on the sustainability of both the resource base and the military mission are complex and challenging. Activities to alleviate one problem can often exacerbate others. All too often, decision-makers on military installations are faced with making critical land management decisions without the benefit of complete environmental information nor complete knowledge of other, competing objectives and/or land use requirements.

Leveraging with other Defense science and technology programs and similar programs in industry and academia, SERDP focuses on the following Conservation research and development objectives to support DoD's Conservation goals:

- Develop standardized, cost effective methods to inventory, characterize, and monitor natural and cultural resources to help ensure compliance with applicable laws and requirements. Where appropriate, use defense-unique data collection and assessment tools to develop these methods.

- Develop and demonstrate more effective methods and techniques to maximize availability of military lands in support of military missions, with minimal impact to natural and cultural resources in a manner consistent with the Services' mission and Federal environmental regulations.

- Develop and demonstrate efficient and effective techniques to conserve and restore natural and cultural resources proactively, particularly threatened and endangered species and the ecosystems on which they depend.

- Develop and demonstrate effective, user-friendly computer-based models to determine the incremental and cumulative impact of military activities on natural and cultural resources, and assess effectiveness of conservation and restoration techniques.

- Develop state-of-the-art techniques to assess and predict the impact of military use on those critical elements of the ecosystem impacting sustainability.

- Develop the needed methods, tools, guidelines, and decision support systems for effectively implementing integrated resource management techniques.

These research and development objectives are addressed and implemented under five related but distinct subthrusts which makes up the Conservation Taxonomy (as depicted in Figure III-4). Current focus areas or critical paths to DoD conservation goals are listed under each subthrust. These focus areas may change from year to year in order for the subthrust to appropriately adapt to new DoD requirements.

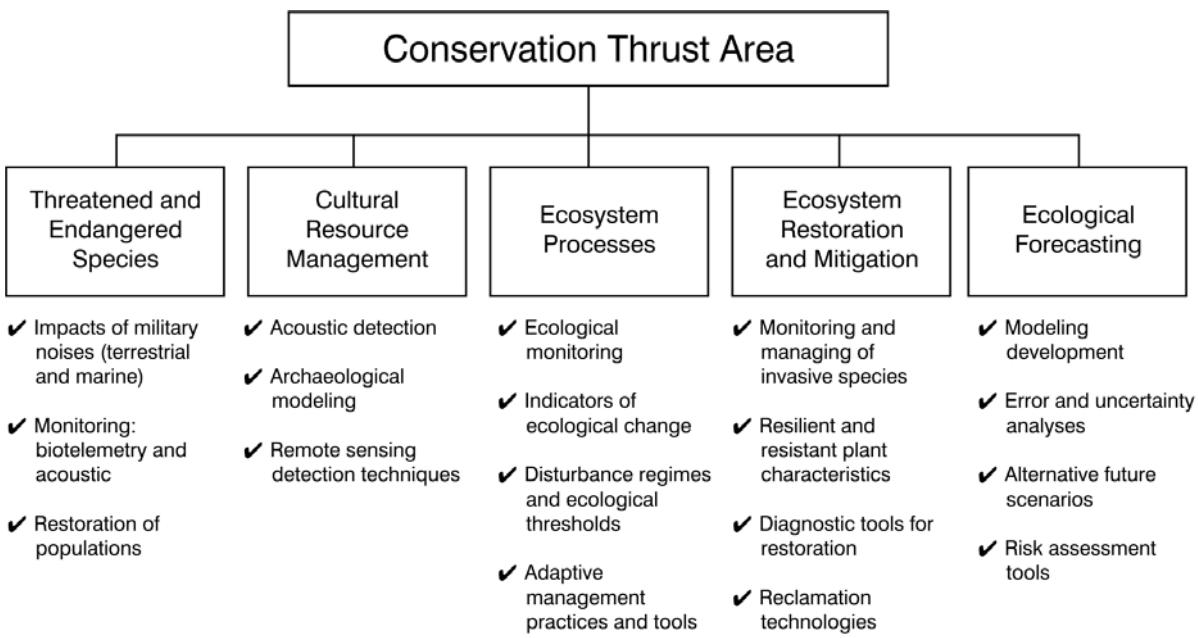

Figure III-4. Conservation Taxonomy.

Principal Driving Requirements

DoD manages species of concern, and specifically Threatened and Endangered Species, to comply with the same laws and statutory provisions as all other Federal Agencies, including the Endangered Species Act

(ESA) of 1973, the Marine Mammal Protection Act of 1972, and the Migratory Bird Treaty Act. In addition, the following legal authorities apply specifically to the management of Threatened and Endangered Species on DoD owned or managed lands: "Conservation Programs on Military Installations (Sikes Act)," National Environmental Policy Act, the Fish and Wildlife Coordination Act, and others. The **Threatened, Endangered, and Sensitive Species** subthrust addresses DoD specific requirements that pertain to those species that are identified as either threatened or endangered (both currently and potentially). It is known that more than 200 installations provide habitat for at least 400 plants and animals that are listed on, or candidates for, the Federal endangered species list. This is the highest known density of threatened and endangered species found on any Federal lands. Research and development must be responsive and as proactive as possible in meeting all DoD requirements pertaining to these plants and animals.

The research and development focus for the Threatened, Endangered, and Sensitive Species subthrust has included the effects of aircraft overfights on birds of prey, biotelemetry, marine mammal responses to low frequency noise, whale monitoring, training noise impacts on the Red-Cockaded Woodpecker, salmon in the Pacific Northwest, and acoustic monitoring of Threatened and Endangered Species in inaccessible areas. The challenge for the Threatened, Endangered, and Sensitive Species subthrust will be to integrate the approaches and findings of research and development pertaining to specific species into the context of an ecosystem management approach. DoD recognizes that a species-by-species approach to resource management is potentially inefficient and can lead to contradictory management strategies. DoD has adopted an ecosystem approach to managing its natural resources. This approach considers groups of plant and animal species, instead of focusing on single-species management. It promotes adaptive management, the use of benchmarks and the best available science, and sustainable use for both human and ecological purposes. One way of doing this will be to integrate regional management strategies more effectively by reducing conflicting individual approaches. Working within an eco-regional context can help protect the viability of resident populations and reduce the likelihood of future listing of species under the ESA.

DoD lands contain more than 100,000 archaeological sites, and at least 200 installations have properties that are listed on or eligible for the National Register of Historic Places. Approximately two percent of all the military's buildings and structures are considered historic. Management of cultural resources on the many and varied military installations in the United States is necessitated by respect and by public laws that include, but are not limited to, the National Historic Preservation Act of 1966 as amended; the Archaeological Resources Protection Act of 1979 as amended; and the Native American Graves Protection and Repatriation Act of 1990. The **Cultural Resource Management** subthrust addresses the research and development needs associated with the detection, sampling, and preservation of cultural resources on DoD installations. The R&D focus for this subthrust has included acoustic detection, archaeological modeling, and remote sensing detection techniques. As a result of a co-sponsored SERDP/Legacy Program Cultural Resource Management workshop in June of 2000, a number of new research and development initiatives were identified in the categories of detection, preservation and data management. The reduction of cost and increase in efficiency are key drivers for defining the research and development investments in the Cultural Resource Management subthrust.

As part of its stewardship goal, DoD is charged to maintain and improve the sustainability and native biological diversity of terrestrial and aquatic (including marine) ecosystems while supporting human needs, including the DoD mission. All of the DoD services have expressed the need to better understand ecological processes and trends on military lands, the ecological relationship of military lands to their surrounding lands, and the interactions between mission activities and ecological processes. The goal of the **Ecosystem Processes** subthrust is to provide knowledge, tools, and techniques to permit military land managers to evaluate the ecosystems on their installation and to predict the responses to military operations as well as to effectively manage the lands for long term sustainability and use. This subthrust focuses on addressing science and technology requirements for ecosystem management of DoD military installations. The current R&D focus for this subthrust includes the creation of long term monitoring site(s) on DoD lands to observe ecosystem trends over time, identifying ecosystem change indicators, understanding disturbance within the ecosystem resulting from military mission activities and land management practices, and development of adaptive management practices and tools based on ecosystem monitoring. The challenge for the Ecosystem Processes subthrust will be to incorporate the findings/result of ecological monitoring and new understanding of ecosystem processes into the development of practical adaptive management tools for installation resource managers that are transferable across an ecoregion.

Within the DoD, the military services are required to maintain and restore remaining native ecosystems across their natural range of variation, and to ensure long-term sustainability of military training and testing lands and waters in support of the National Defense mission (DoD Instruction 4715.3). The **Ecosystem Restoration and Mitigation** subthrust addresses the research and development needs associated with the restoration of natural systems and their functions and values, with a goal of sustaining the health, productivity, and biological diversity of ecosystems in concert with the mission of military readiness and environmental compliance requirements. The research and development focus for the Ecosystem Restoration and Mitigation subthrust includes monitoring and managing of invasive species, identification of resilient and resistant plant characteristics, diagnostic tools for restoration, and reclamation technologies. In practice, much of DoD's restoration efforts are engineering driven and site specific without much regard to the significance of the functions in which the site(s) serves within the ecosystem or ecoregion. With the increased emphasis on an integrated ecosystem-based approach to management of Federal, State, and private lands, ecosystem restoration has emerged as an important area of interest. To be fully realized and implemented, ecosystem restoration requires the integration of the understanding of ecological processes into reclamation technologies and engineering practices. The goal of the Ecosystem Restoration and Mitigation subthrust is to identify research and development opportunities that will facilitate this integration.

Ecosystems provide the background for the DoD to maintain its military readiness. To sustain these ecosystems, decisions makers must take into account potentially interactive effects of natural variability and human induced change on ecosystem structure, function and productivity. A key role of science is to provide insights into the potential scale, direction, and nature of that change. SERDP funded research and development in the **Ecological Forecasting** subthrust is aimed at forecasting the ecological response to current and/or expected change using models and other decision-making tools. The current R&D focus for the Ecological Forecasting subthrust includes modeling development, error and uncertainty analyses, alternative future scenarios, and risk assessment tools.

A key driver over the next decade for the Ecological Forecasting subthrust will be urban change in areas surrounding DoD installations. Research and development should have a critical contribution to the establishment of a comprehensive understanding of the dynamics of urban change outside DoD installations and how this change will effect the sustainability of military range lands. Decision tools will be instrumental for the development and implementation of installation-community planning policies, procedures and forums, as well as, serving to facilitate daily management decisions on DoD installations.

Conservation Program

For FY 2001, Conservation received approximately 14 percent of the SERDP budget. SERDP conducted two solicitations that requested project proposals in the Conservation Thrust Area and supported a total of 19 Conservation projects. Four projects are listed under the Threatened and Endangered Species subthrust. One completed project assessed training noise impacts on the Red-Cockaded Woodpecker. Two new projects are addressing acoustic techniques for monitoring whales. An acoustic monitoring technique for the black-capped vireo and the golden-cheeked warbler is being demonstrated by another new project, as well. SERDP's Ecosystem Management Project (SEMP) manages three research efforts under the Ecosystem Processes subthrust. These projects focus on

CONSERVATION

FY 2001	
19	Total projects
5	Completed projects

FY 2002	
21	Total projects
7	New Start projects*

* Does not include projects to be funded under the FY 2002 Supplemental Solicitation.

indicators of ecological change and defining disturbance thresholds. Of the seven projects addressing Ecosystem Restoration and Mitigation subthrust, four projects focus on the detection and control of invasive species. One project identifies resilient plant characteristics and develops wear resistant plant cultivars for use on military training lands. Another project develops diagnostic and reclamation technologies for mitigation impacts to arid lands from military activities. One new project addresses riparian restoration and enhancement strategies. Seven projects are listed under the Ecological Forecasting subthrust. Two of these projects have quantified error and uncertainty related to ecological modeling and simulation. Another completed project developed a ecosystem fragmentation model. The use of remote sensing technologies for ecosystem management is being investigated by one project. Further enhancements to the Army Training and Testing Area Carrying Capacity (ATTACC) methodology is the focus of another project under this subthrust.

During FY 2001, the SERDP Conservation Thrust Area solicited proposals and approved a total of nine new start projects that will focus on (1) remote sensing techniques for the detection and evaluation of cultural resources; (2) impacts of fog oil on the food sources of TES; (3) impacts of regional land-use change on the sustainability of military installations and (4) the development of sensors for monitoring metals and other environmental parameters.

Two new start projects were selected for funding in FY 2002 to address detection and identification of archeological sites and features using radar techniques. Methods for assessing the impact of fog oil on insect food sources for TES will be investigated by one project using wind tunnel experiments. Three projects will address the impacts of regional land-use change on the sustainability of military installations. Two out of the three will be modifying existing land-use models to be used as predictive tools specific to military installations, and one will be enhancing an alternative future scenario model to increase the transferability of the model to military installation personnel. Three, one-year efforts will be developing innovative sensors or sensor systems for the detection of metals and other environmental parameters.

Late in FY 2001, the supplemental solicitation (mentioned previously) with FY 2002 funding issued one Conservation SON. Due to the late timeframe, new projects from this solicitation could not be included in this Report. The SON from the supplemental solicitation is briefly described below. All SONs are further described in detail in Appendix F.

The objective of the FY 2002 Supplemental Solicitation SON, entitled **The Impact of Military Training Activities, Land Management Actions and Species/Habitat Sensitivities on Terrestrial Threatened and Endangered Species**, is to develop or apply methods and technologies that evaluate the effects of and possible interrelationships between military operations (training activities and land management actions) and species/habitat sensitivities on the occurrence and vitality of threatened or endangered species. Specifically, the DoD needs to better characterize the impact from military operations on TES and/or their habitats by quantifying disturbance and species/habitat sensitivities.

The following list reflects projects completed in FY 2001 and projects continuing into FY 2002. Also included are titles of projects that begin in FY 2002. Complete descriptions of all of the projects for FY 2001 and FY 2002 may be found on the pages referenced in Appendix C - Conservation Project Summaries.

Subthrust: *Ecological Forecasting* — Page

FY 2001 Completed Projects

FY 2002 Continuing Projects

FY 2002 New Start Projects

Subthrust: *Ecosystem Processes*

FY 2001 Completed Projects

None

FY 2002 Continuing Projects

FY 2002 New Start Projects

Subthrust: *Ecosystem Restoration and Mitigation*

FY 2001 Completed Projects

None

FY 2002 Continuing Projects

FY 2002 New Start Projects

None

Subthrust: *Threatened and Endangered Species*

Subthrust: *Cultural Resource Management*

FY 2003 Conservation Initiatives

The FY 2003 initiatives reflect an emphasis on (1) the U.S. Army's threatened and endangered species user requirements, (2) the development of advanced technologies to map and assess coral reef communities and other benthic marine habitats for DoD, and (3) the management and restoration of estuarine ecosystems.

An FY 2003 SON for the Threatened and Endangered subthrust area is entitled **Impact of Military Training Activities, Land Management Action and Species/Habitat Sensitivities on Aquatic Threatened and Endangered Species**. The objective of this initiative is to develop or apply methods and technologies that evaluate the effects of, and possible interrelationships between, military operations (training activities and land management actions) and species/habitat sensitivities on the occurrence and vitality of aquatic threatened or endangered species (TES). The results of efforts proposed under this Statement of Need (SON) will provide, in accordance with the Endangered Species Act, the basis for future biological assessments, biological opinions and endangered species management plans. This information will contribute to the development and implementation of TES management and recovery plans while maintaining military readiness. Additionally, the proposed work is expected to contribute to the implementation of an adaptive management process (i.e., a management process that adapts to changes in disturbances to maintain ecosystem integrity) on installations. The DoD needs to provide quantifiable measures to properly assess the effects of its activities on listed species and land managers need to use these measurements to support land management practices that adapt to the demands of military training.

The FY 2003 SON entitled **Estuarine Ecosystem Management and Restoration** supports initiatives under both the Ecosystem Process and Ecosystem Restoration and Mitigation subthrusts. The main objectives of this SON is to (1) evaluate the environmental impacts of military activities on estuarine ecosystems and (2) develop restoration/enhancement methods and conservation management techniques to minimize these impacts and sustain the beneficial qualities of estuarine ecosystems within DoD installations. Research fulfilling the objectives of this SON will provide DoD with an increased scientific understanding of how estuarine ecosystems respond to anthropogenic stresses as a result of military combat training and other activities on DoD lands. A better understanding of stress-response relationships influencing estuarine ecosystem functionality will enable DoD to better predict and mitigate the impacts of its activities on these systems. The development of effective restoration/enhancement methods and ecosystem management techniques will increase DoD's ability to protect and sustain critical ecosystem functions while maintaining essential military activities such as realistic training exercises.

Under the Ecosystem Processes subthrust, the FY 2003 SON entitled **Assessment of Benthic Communities for the Department of Defense** supports development of advanced technologies to map and assess coral reef communities and other benthic marine habitats. Research fulfilling the objective of this SON will provide operators and natural resources personnel with the means to collect and analyze comprehensive knowledge of benthic habitats and coral reef communities under DoD purview. This information is necessary for operational and environmental planning and will provide decision-makers with crucial information needed to maintain compliance. Obtaining quantitative baseline data is an important element not only for Federal coastal management of protected resources but to provide a foundation for environmental documentation necessary to conduct military operations. The information garnered from this effort will assist DoD in ensuring maritime sustainability by providing operators with a firm foundation on which to plan future training exercises and other operations in areas containing coral reef communities. It will also form the basis of all environmental planning documentation prepared for such activities occurring in these areas.

POLLUTION PREVENTION

Introduction

The DoD and DOE have a number of unique functions, such as the development and operation of sophisticated weapons systems, which demand specialized, high-performance materials. Many of these materials are toxic and are targeted for voluntary reduction. The challenge to DoD and DOE is sustainability, which translates to finding new high-performance materials that are not toxic and/or to determine innovative ways to control the use of toxic chemicals in order to reduce releases and off-site transfers.

The SERDP Pollution Prevention Technology Thrust Area focuses on reducing or eliminating the generation of pollution within the DoD. The application of pollution prevention technologies will influence positively the other DoD environmental Thrust Areas by encouraging the use of innovative technologies and practices such as recycle, recovery and reuse, reducing pollutants to be managed at the source, and promoting the sustainable use of natural resources.

As defined under the Pollution Prevention Act of 1990, pollution prevention means "source reduction" and other practices that reduce or eliminate the creation of pollutants through increased efficiency in the use of raw materials. Source reduction is defined as any practice that reduces the amount of any hazardous substance, pollutant, or contaminant entering any waste stream or otherwise released into the environment (including fugitive emissions) prior to recycling, treatment, or disposal.

The Pollution Prevention Thrust Area, at the recommendation of the SERDP Scientific Advisory Board, is adopting a proactive approach to provide solutions to the highest priority defense-related environmental problems. The Pollution Prevention Thrust Area, in addition to addressing near-term multi-service DoD problems, also will address more forward looking, high-risk, long- term projects to achieve the goals that will be set forth by future regulations. For example, the development of the next generation of environmentally advantaged DoD systems is key to meeting potential future regulations. This will be done by designing tools to alert planners to potential environmental issues. SERDP will work closely with military planners, Service research organizations, and the Office of Deputy Under Secretary of Defense for Installations and Environment to identify long-term needs for the DoD.

The Pollution Prevention Technical Thrust Area Working Group (TTAWG) continues to emphasize a program shift toward the more global, Tri-Service issues and on developing seed technologies to address emerging regulatory issues. The TTAWG has envisioned SERDP's role as a facilitator in communication and collaboration to enhance technology transfer and to leverage Service and SERDP resources. This will be achieved through increased interaction with the National Defense Center for Environmental Excellence (NDCEE), the National Center for Manufacturing Sciences (NCMS), and participation in Joint Group on Pollution Prevention (JG-PP).

The primary DoD environmental concerns in Pollution Prevention are:

- Identifying alternatives for hazardous and toxic chemicals and materials
- Reducing the use of hazardous and toxic chemicals and materials
- Reducing the volume and toxicity of wastes and pollutants through source reduction
- Improving the efficiencies of mechanical and chemical systems
- Incorporating environmental ramifications as key evaluation considerations in major system design and acquisition
- Considering the life-cycle effects of materials and systems
- Evaluating the sustainable use of resources

These DoD Pollution Prevention needs are addressed by the five major sub-thrust areas of Air Emissions, Halon Replacements, Elimination of Chromium and Cadmium, Green Energetic Materials, and Reduction of Hazardous Materials and Solid Waste, and further delineated in Figure III-5.

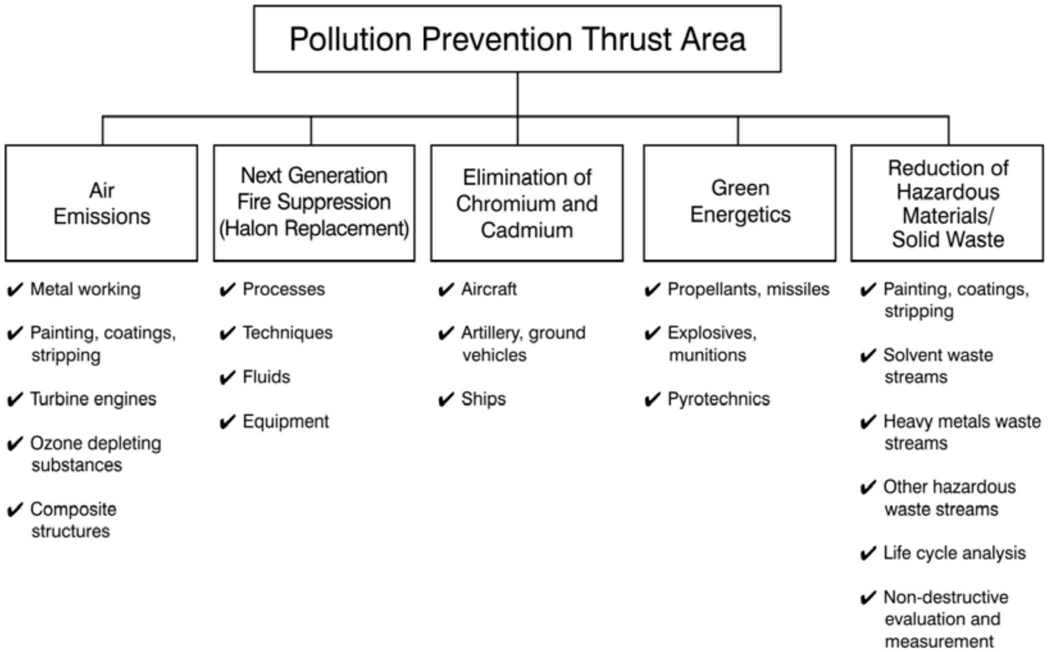

Figure III-5. Pollution Prevention Taxonomy.

Future SERDP Pollution Prevention projects will be selected based on the following general metrics:

- Expected payoff (i.e., potential cost avoidance)
- Magnitude of the environmental problem that the technology will address
- Clearly identifiable potential environmental benefits and impacts on the defense establishment, regardless of whether the project addresses current, near-, mid-, or long-term needs
- Leveraged funding from Services/Agencies applied to the project

Principal Driving Requirements

Congress has enacted several laws that are primary drivers for DoD and DOE to green up their manufacturing, production, and repair operations. Just a few include the Clean Air Act, Clean Water Act, Pollution Prevention Act, Resource Conservation and Recovery Act, Solid Waste Disposal Act, and Toxic Substances Control Act. The White House has also directed the Federal Government through a series of Executive Orders (EO) to take actions to prevent pollution. In 1999, EO 13123 "Greening the Government Through Efficient Energy Management," and EO 13134 "Bio Based Products and Bioenergy," were signed by the President. In April 2000, EO 13148 "Greening the Government Through Leadership in Environmental Management" directed DoD and other Federal agencies to establish new pollution reduction goals. In response, DoD has implemented three new reduction goals: (1) reducing the Toxic Release Inventory by 40% by 2006; (2) reducing the use of 15 chemicals by 2006 by focusing on replacement of common processes and chemicals; and (3) eliminating the purchase of all Class I OSDs by December 31, 2010.

In the **Air Emissions** subthrust, SERDP is funding a wide array of projects addressing reduction or elimination of VOCs in adhesives, lubricants, and sealants, pollutants in composites and low observable coating, and emissions from engines. The 1990 Clean Air Act Amendments (CAAA), the Resource Conservation and Recovery Act (RCRA), and state and local regulations restrict the emission and disposal of these hazardous materials. Ozone depleting substances (ODS) are being phased out of production under national policy and international (Montreal) protocol. DoD directives require significant reductions in hazardous wastes and development of alternative materials and processes that meet environmental restrictions and allow DoD to continue operations. Operations and training activities at DoD installations and facilities generate large quantities of hazardous, non-hazardous, and special wastes that are expensive to manage and dispose.

The replacement of Halon, an ODS , in fire fighting technologies is a major focus of research in the **Next Generation Fire Suppression** subthrust. Halon 1301 (CF3Br) has long been the choice for fire extinguishment in most weapon systems and mission-critical facilities. However, due to its high ozone-depletion potential, halon 1301 was banned from production as of January 1, 1994, under the Copenhagen Amendments to the Montreal Protocol on Substances that Deplete the Ozone Layer. The objective of this subthrust is to develop and demonstrate environmentally acceptable and user-safe processes, techniques and fluids that meet the operational requirements currently satisfied by Halon 1301 systems in aircraft, ships, land combat vehicles, and critical mission support facilities. The results will be specifically applicable to fielded weapons systems and will provide dual use fire suppression technologies for preserving both life and operational assets. The benefits of this subthrust will be demonstrated alternatives to halon 1301 usage that will enable DoD weapon system managers to make prudent decisions in removing their dependence on a key zone-depleting substance in a manner that offers the least fiscal and operation barriers to implementation.

The research in the **Elimination of Chromium and Cadmium** subthrust focuses primarily on finding environmentally friendly sealants and coatings as well as better application methods. Sealants are required in aircraft systems and on weapons to provide protection against corrosion, prevent moisture entry, provide a fuel barrier, and provide electrical insulation. Traditionally, sealants use chromium as the primary corrosion inhibiting substance. Chromium has been designated as hazardous and is targeted for elimination in order to comply with either current or pending Occupational Safety and Health Administration (OSHA) requirements. Most sealants also contain VOCs such as methyl ethyl ketone (MEK) and toluene. The DoD and DOE have committed to replace chromate-based metal finishing in present and next generation systems. It is well known that chromates pose a significant toxic hazard to human health and their use has been subject to strict regulation. It is the desire of regulating agencies, manufacturers and the user community to replace chromate corrosion protection technologies. Chromate corrosion protection technologies will only be replaced when environmentally friendly corrosion protection technologies achieve acceptable levels of performance. Significant, strategic investments in chromate elimination research have been made, and these efforts have contributed significantly to our understanding of corrosion protection by chromates.

The **Green Energetics** subthrust assesses the current environmental issues associated with energetic materials and energetic material-containing systems to identify major areas of concern and investigate innovative technologies for the synthesis of environmentally friendly ammunition, propellants, and smokes. In an effort to address medium caliber ammunition (20mm to 60mm in size) environmental problems in a systematic manner, SERDP recommended that an umbrella program approach be utilized. In response, the Army solicited the medium caliber ammunition technical community for membership on the Technical Advisory Committee (TAC) to better focus on the large number of diverse environmental issues. Based on TAC recommendations, key areas of interest include a green priority matrix identifying specific contaminants and quantities. The matrix assigned a high, medium, or low priority for the various contaminants and calibers involved. Elimination or replacement of lead and toxic heavy metals was deemed highest priority based on the pollution contribution quantity and toxicity. Primary sources of these materials in medium caliber ammunition are the primer and detonator in the fuze. The development of environmentally benign alternatives will reduce or eliminate range contamination; mitigate the long term exposure effects on plant, wildlife, and water systems, and drastically curtail the use of toxic materials at the various 20mm to 60mm ammunition manufacturing facilities. It will also result in reduced safety risks and reductions in prolonged exposure of both user and production personnel to harmful levels of contaminants and combustion products that occur in the material handling and disposal of toxic materials during production, test, and operational use of medium caliber munitions. Economic benefits include reduced ammunition, training and production site cleanup costs. Significant cost avoidance could be realized through elimination of approximately 10 tons of lead required to support production of medium caliber training ammunition over the next six years.

During this decade, an increased emphasis has been placed on pollution prevention to reduce environmental impacts associated with DoD weapon systems acquisition. The DoD Pollution Prevention Strategy of August 11, 1994, established a goal to identify and develop environmental life cycle cost estimating tools that inject pollution prevention and other environmental concerns into acquisition decisions. Development and application of modeling and simulation tools to identify and test technical solutions that reduce reliance on toxic materials and processes are required. Within the **Reduction of Hazardous Waste/Solid Waste** subthrust, SERDP is funding numerous, wide-ranging projects addressing alternatives to hazardous and toxics chemicals and processes such as for cleaning agents, anti-freeze, corrosion protectors, and coatings as well as the reduction of solid waste associate with the packaging of military rations. Virtually all DoD maintenance and repair activities for weapon system components involve the use of toxic or hazardous substances. In 1998, EO 13101 directed "Greening the Government Through Waste Prevention, Recycling, and Federal Acquisition." It encouraged the expansion of markets for recovered materials, environmentally preferable products, (including biobased products), and established the organizational structure to ensure full accountability. Under this EO, Federal agencies must establish specific goals for (1) waste prevention and recycling or solid waste diversion, (2) affirmative procurement of products that are made with recovered materials, and (3) procurement of environmentally preferable products and services for which a pilot project has been successfully completed. Agencies will annually evaluate their progress toward attaining these goals.

Additionally, SERDP continues to use topical studies and workshops as tools to identify DoD/DOE user needs, to better understand the existing state-of-the-art technology in these areas, and to identify environmentally driven requirements. In addition to fostering technology transfer, this information is used to help focus the SERDP program on the highest priority issues and to avoid duplication of effort. SERDP's Pollution Prevention program has taken a systems approach to continue to work on the next generation of concepts/materials through the development of SONs derived from DoD user requirements. In FY 2001, SERDP sponsored a joint services workshop to identify specific service Depot-level issues that could be structured into SERDP SON. The requirements generation process maintained by each Service (Navy, Army and Air Force) provided the overall foundation for this workshop. These requirements, generated by the individual services, are essential to the determination of what issues should be brought forward to the SERDP program for consideration. Goals for this workshop were to identify common Depot issues, define technology needs, and to introduce the requirements owners to the Depot customers. The intent was to generate a listing of Depot environmental issues that would help the SERDP TTAWGs to develop Statements of Need. The workshop provided an opportunity for communication between the Requirements, Depot and SERDP communities. These communication lines will enhance future efforts to provide guidance and devote resources to the pressing environmental issues that continue to face the DoD.

Leveraging with other DoD, DOE, and EPA science and technology programs and industry, the Pollution Prevention subthrust areas focus also on the following research and development objectives:

- Alternative materials and processes to replace defense use of hazardous heavy metals (e.g., lead, nickel) and metallic compounds and hazardous air pollutants

- Techniques to regenerate, recycle, and re-use defense unique toxic chemicals and materials

- Cost-effective, environmentally preferable packaging and recycling approaches to reduce generation of solid waste from defense-related operations

- Predictive models (which include environmental life cycle costing) to aid in the development of environmentally sound weapon systems and platforms during concept development, design, test and evaluation, maintenance (logistics support documentation), and decommissioning

Pollution Prevention Program

POLLUTION PREVENTION	
FY 2001	
30	Total projects
7	Completed projects
FY 2002	
34	Total projects
11	New Start projects*

* Does not include projects to be funded under the FY 2002 Supplemental Solicitation.

For FY 2001, Pollution Prevention received approximately 27 percent of the SERDP budget. SERDP conducted three solicitations that requested project proposals in the Pollution Prevention Thrust Area and supported a total of 30 projects. Late in FY 2001, the supplemental solicitation (mentioned previously) with FY 2002 funding issued three Pollution Prevention SONs. Due to the late timeframe, new projects from this solicitation could not be included in this Report. The three SONs from the supplemental solicitation that focus on medium caliber munitions are briefly described below. All SONS are further described in detail in Appendix F.

Efforts to promote the "greening" of medium caliber munitions resulted in three SONs. The objective of the first FY 2002 Supplemental Solicitation SON, entitled **Environmentally Acceptable Small, Electro-Explosive Devices For Medium Caliber Munitions,** is to develop environmentally benign, small, electro-explosive devices (EEDs) (detonators). These small EEDs (detonators) are to be sized such that they will be compatible (volume, weight and power) with the newest fuses being developed for medium caliber (20-60mm) ammunition and have sufficient output energy to initiate lead and main charges containing "insensitive" explosives. These detonators currently use lead styphnate, lead azide and HMX in their construction and all of these are considered to be hazardous/toxic materials. In the second FY 2002 Supplemental Solicitation SON, entitled **Environmentally Acceptable Incendiary Compositions For Medium Caliber Ammunition,** the objective is to develop alternative chemistries to eliminate the use of toxic, heavy metals and volatile organic chemicals (VOC) that are currently used in the manufacture of incendiary compositions for medium caliber (20mm - 60mm) ammunition applications. The result should be technologies, methods, or processes that develop or evaluate the use of alternative fuels and/or oxidizers that are environmentally benign and eliminate or minimize the use of VOCs in the manufacturing process of incendiary materials. Finally, the SON entitled **Percussion Primers For Medium Caliber Ammunition** seeks to reduce or eliminate environmentally unacceptable materials used in the formulation or manufacture of percussion primers and ignition booster pellets for medium caliber (20mm to 60mm) military ammunition. The result should be technologies, methods, and processes that result in alternative primer compositions that are environmentally benign and provide comparable or increased levels of performance in accordance with the appropriate military specifications.

The following list reflects new projects started late in FY 2001, projects completed in FY 2001, and projects continuing into FY 2002. Also included are titles of projects that begin in FY 2002. Complete descriptions of all of the projects for FY 2001 and FY 2002 may be found on the pages referenced in Appendix D - Pollution Prevention Project Summaries.

Subthrust: *Air Emissions* **Page**

FY 2001 Completed Projects

FY 2002 New Start Projects

None

Subthrust: *Green Energetics*

FY 2001 Completed Projects

FY 2002 Continuing Projects

FY 2002 New Start Projects

Subthrust: *Reduction of Hazardous Materials*

FY 2001 Completed Projects

FY 2002 Continuing Projects

FY 2002 New Start Projects

FY 2003 Pollution Prevention Initiatives

SERDP is proposing ten new Pollution Prevention initiatives through the issuance of eight core SONs plus two SEED SONs. The focus of the FY 2003 program is development of environmentally benign chrome-free coatings that lead to or provide a scientifically based foundation for coatings and process that do not use or produce toxic substances and reduces or eliminates volatile organic compounds and hazardous air pollutants. The pollution prevention program will also seek out and develop new technologies for environmentally friendly electroplating and surface finishing processes for aircraft weapon systems and identify innovative solutions for liquid spray paint within the DoD and DOE complexes. SERDP will continue to act as a catalyst in fostering the development of next generation concepts and tools, such as improved computational chemistry techniques and models which will help accelerate the development of environmentally friendly DoD materials and processes, including energetic materials.

The objective of the first core SON, **Chromium-Free Coating Systems for DoD Applications**, is to develop an environmentally benign chromium-free, low volatile organic compounds (VOCs), low hazardous air pollutants (HAPs) coating system for metal alloy structural components in DoD systems. The results of this research may integrate various efforts in DoD and industry to find chromium-free coating compounds that lead to, or provide a scientifically based foundation for, coatings and processes that:

- do not use or produce hazardous toxic substances and reduces or eliminates VOCs and HAPs
- offer corrosion protection and other properties that meet or exceed performance levels of current products and processes
- can be produced and maintained within the DoD operational framework without excessive cost

The objective of the second core SON, **Environmentally Innovative Technologies for Metal Parts Cleaning for Electroplating and Surface Finishing**, is to develop affordable, non-hazardous materials and processes for metal parts cleaning while meeting unique component requirements for DoD systems. Specifically, the goal of this research is to develop qualified replacements for the chlorinated solvents used in cleaning metal parts. The proposed work should address one or both of the following objectives:

- Proposed materials and processes must be addressed from a systems level and exhibit lower life cycle environmental impact than current processes and similar economics.
- Depot support issues (maintenance and repair) and systems applications must be considered.

The objective of the third core SON, **Environmentally Acceptable Alternatives for Liquid Spray Paint Pre-Mix Components**, is to develop an alternative approach to current two-part liquid paint mixtures used for wet-spray painting. Specifically, this effort seeks to develop new, environmentally benign coatings that can be stored in dry powder form and mixed with an environmentally benign liquid for application by wet-spray techniques. Use of these materials shall eliminate or reduce the release of volatile organic compounds and hazardous air pollutants and provide extended storage and shelf-life characteristics.

The objective of the fourth core SON, **Environmentally Innovative Technologies for Electroplating and Surface Finishing: Alternatives to Nickel Electroplating**, is to develop alternatives to nickel plating to eliminate the generation of nickel air emissions and hazardous waste in DoD industrial operations. Areas of research might involve process alternatives or materials substitution. Alternative materials suggested for conventional processes must have little or no environmental, safety or health. Proposed materials and processes must be addressed from a systems level and exhibit lower life cycle environmental impact that current processes and similar economics.

The objective of the fifth core SON, **Environmentally Benign Methods for the Removal of Radar Absorbing Material (RAM) Coatings**, is to develop new, environmentally benign methods and/or materials for the removal of radar absorbing material (RAM) coatings from currently fielded and/or future DoD systems. Specifically, the goal is to develop materials and processes that eliminate or significantly reduce the volatile organic compounds (VOCs), hazardous air pollutants (HAPs), and hazardous waste that result from using the current class of "environmentally advantaged" chemical strippers. The proposed work should address the following objectives:

- Proposed research must be addressed from a systems level.
- Proposed research must exhibit the potential for lower environmental life cycle impact than current systems.
- Must not degrade weapon/coating system performance.

The objective of the sixth core SON, **Green Synthesis Techniques for Energetic Ingredients and Their Precursors**, is to develop innovative green chemistry approaches for use as efficient, environmentally responsible techniques to produce energetic ingredients (EIs) and their precursor materials for DoD applications. These include, but are not limited to, nitramines, nitroaromatics, and related compounds. Areas of interest include:

- synthesis approaches for energetic ingredients and precursor formation, nitration processes, or synthesis of nitrogen-containing polycyclic compounds
- improving selectivity and efficiency in aromatic nitration reactions

The objective of the seventh core SON, **Environmentally Acceptable Stab Detonators for Medium Caliber Munitions**, is to develop new, small, impact initiated devices (IIDs) for DoD medium caliber munitions that are environmentally benign compared to the current designs. The existing detonators contain hazardous compounds including lead styphnate, lead azide, tetracene, and barium nitrate. The new IIDs should meet the following objectives:

- designed such that the output from the device will cause a lead or main explosive charge to detonate
- sized such that they will be compatible with the current fuzes being produced for medium caliber ammunition and have sufficient output energy to initiate lead and main charges
- ultimately provide the same relative level of affordability as the current designs

The objective of the eighth core SON, **Environmentally Acceptable Propellant Compositions for Medium Caliber Ammunition**, is to reduce or eliminate environmentally unfriendly materials used in the formulation and manufacture of gun propellants for military ammunition with the intent of early transition to medium caliber ammunition. Specifically, the goal is to identify suitable alternatives for diphenylamine and barium nitrate in these formulations.

In addition to these core SONs, SERDP is also soliciting SEED proposals to develop high risk/high payoff research and development efforts to address the DoD pollution prevention needs.

The objective of the first SEED SON, **Environmentally Acceptable Alternatives for Lithium Reserve Batteries for Medium Caliber Munitions**, is to develop environmentally benign power supplies for future medium caliber ammunition applications. The power supply will be expected to provide a minimum of 4 volts with a current drain of between 20 and 200 milliamps for up to tens of seconds, depending upon the circuit design plus the number and types of sensors onboard the fuze. In addition, these power supplies must ultimately provide the same relative level of affordability as current designs.

The objective of the second SEED SON, **Environmentally Acceptable Alternatives For Chromated Shielded Metal Arc Welding Rods**, is to develop non-chromated shielded metal arc welding (SMAW) electrodes to replace the existing chromated electrodes which are used to weld stainless steel. Specifically, the proposed effort shall identify and demonstrate the feasibility of concepts to fabricate chromium-free electrodes for these applications. Ultimately, these electrodes will be expected to meet or exceed the performance of the current classes of electrodes while reducing the levels of hazardous air pollutants and toxic emissions.

UXO

Introduction

Formerly a subthrust within the Cleanup Thrust Area, **Unexploded Ordnance (UXO)** has been identified by the Services as the highest priority user need. UXO presents a major challenge to DoD in its effort to remediate closed, transferred, and transferring (CTT) ranges, such as sites designated for base realignment and closure (BRAC) and formerly used defense sites (FUDS). It also is a challenge for active military installations seeking to manage their test and training ranges as sustainable assets. In the United States alone, current estimates indicate that more than 50 million acres of land with varying terrain, vegetation, and topography are potentially contaminated with UXO. Using current technologies, cost estimates of identifying and disposing of UXO in the U.S. range from $10's of billions to over $100 billion. New technologies capable of detecting UXO with high detection rates and low false alarm rates are required to reduce drastically the cost of site characterization and cleanup.

Until recently, "mag and flag" was the standard procedure for site characterization for UXO. In a "mag and flag" operation, a magnetometer or electromagnetic induction sensor is used and anomalies are identified by real-time human interpretation of sensor response, which is usually an audible signal set at some operator-determined threshold. Technical capability has developed beyond "mag & flag" for open terrain. However, advances are still needed in the areas of detection, discrimination, and statistical sampling techniques for wide-area surveys, vehicle and man-portable production surveys, and individual item interrogation under a variety of operational conditions.

The DoD is focused on protecting human health and the environment, reduce remediation costs, and provide timely cleanup of UXO-contaminated sites. Technology objectives for the DoD are:

1. develop tools to perform initial assessment of sites that require large area survey;
2. develop tools to provide detailed site characterization;
3. develop tools for cost-effective, cued object discrimination;
4. develop advanced sensors and innovative data processing and data fusion techniques for increased discrimination between UXO and non-UXO items;
5. develop tools for assessment and quantification of risk;
6. develop standards and protocols for navigation, geolocation, and data acquisition and processing; and

7. develop tools to aid in the cost-effective removal and disposal of UXO.

These technology objectives are addressed by the three major subthrust areas depicted and further defined in Figure III-6.

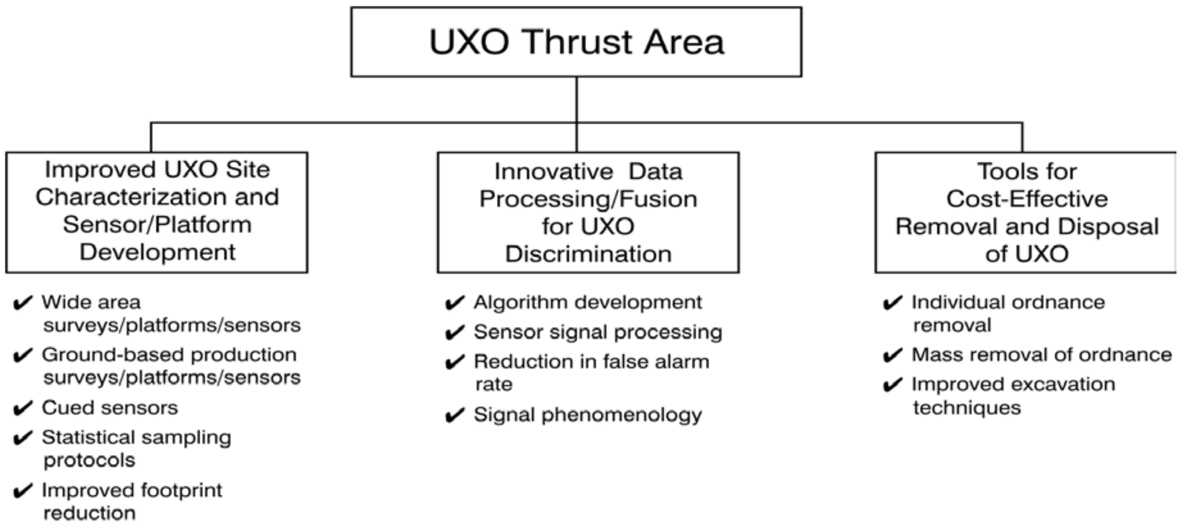

Figure III-6. UXO Taxonomy.

While many defense UXO characterization and remediation situations will require that technologies be identified in the near-term, additional research in this area has the potential to provide the highest return on investment. The Department requested and Congress appropriated an additional substantial increment of funds for FY 2002 specifically to conduct UXO-related research. These projects will be initiated later in FY 2002.

Principal Driving Requirements

The first subthrust area in UXO, **Improved UXO Site Characterization and Sensor/Platform Development**, seeks to develop better site investigation, survey and data collection technologies for locating and characterizing UXO on UXO-contaminated lands. Technologies pursued under this subthrust can be grouped under broad technology objectives:

- ***Wide Area Assessment:*** Develop system capabilities to perform initial rapid assessments of large area sites. UXO is not uniformly distributed; a reproducible engineering methodology is needed to locate concentrations of UXO and reduce the area required for intensive and intrusive surveys (footprint reduction). Such a methodology can significantly reduce the cost of site characterization and enhance the overall management of large sites.

- ***Production Ground Surveys:*** Develop capabilities to provide detailed site characterization. The requirement of these technologies would be to detect individual ordnance items for excavation and disposal. Reduction in false alarm rates, increased detection probabilities, and better characterization of the subsurface UXO can significantly reduce the cost and residual risks of response and allow more rapid and safer transfer of land.

- ***Cued Identification:*** Develop capabilities for non-intrusive cost-effective cued object identification. The task of this system is to correctly identify suspected items. Systems are required to further characterize anomalies identified by a production survey as ordnance/non-ordnance and to determine whether exposed ordnance objects are inert or live.

- ***Procedures/Protocols for Assessing UXO Sites:*** Develop tools to identify and evaluate the risk related to decisions made in the initial assessment and eventual characterization of UXO-contaminated sites. Tools are needed to address the fact that: (1) current UXO detection procedures do not reliably locate all UXO items at a site; (2) in the future, it is likely that decisions will be made to leave anomalies uninvestigated based on advanced discrimination tools, which will still have, however, some failure rate; and (3) area delimitation/footprint reduction currently is and will continue to be imperfect. At most sites, UXO is concentrated in specific areas and effective footprint reduction is a goal so that resources can be focused in the area of highest contamination. Supporting footprint reduction decisions, protocols developed with SERDP funding will fulfill the need for a statistically defensible procedure to assess sites through sub-sampling.

Overall, these novel technologies funded under this subthrust will improve the assessment and characterization of DoD lands with UXO and significantly reduce costs for the eventual remediation of UXO-contaminated sites.

The second UXO subthrust, **Innovative Data Processing/Fusion for UXO Discrimination**, focuses on improved data analysis techniques and software advances (signal processing, algorithms, etc.) that will enable DoD to more accurately and effectively characterize UXO-contaminated sites. Technology pursued under this subthrust revolves around the two most important metrics used to characterize a site contaminated with UXO, namely: (1) the probability of detection (Pd) and, (2) the probability (or frequency) of declaring that a UXO object is present when none is there (false alarm rate). At many current sites, over 75% of the costs to respond are spent excavating non-UXO items. Technologies that do not meet their detection goals result in an unacceptable residual risk to the public. Developing innovative data processing and data fusion technologies will both maximize the Pd and minimize the false alarm rate. Thus, advances in the ability to accurately and cost-effectively characterize and discriminate UXO have a great potential for significantly reducing the hazards associated with UXO, minimizing the impact of UXO cleanup on the environment, and significantly reducing the cost and time required to complete a UXO-contaminated site cleanup.

The third subthrust area in UXO, **Tools to Aid in the Cost-effective Removal and Disposal of UXO**, involves developing DoD's capabilities to reduce the cost and environmental impact associated with the eventual remediation of UXO-contaminated sites. Currently, the excavation and removal of UXO is done manually by a highly experienced UXO technician. In general, an item is removed by careful use of shovels and garden trowels removing thin layers of soil. This exposes the technician to an explosive risk. The UXO item is then either disposed of by explosion in place or removed for storage and future action. Many items are contaminated with explosive residue and may require a response action. A UXO removal and disposal system is needed to safely remove and dispose of these items while minimizing the risk to humans. Advances are expected to involve technologies that relate to remote excavation, identification, sorting, and disposal. The ultimate objective for heavily contaminated areas would be a system that excavates the UXO-contaminated soil, sorts out the ordnance and explosive items, and breaks them down into inert components for scrap disposal.

Leveraging with other defense science and technology programs and industry, the UXO Technology Thrust Area focuses on a subset of the R&D objectives that are listed under the Cleanup Thrust Area. Namely, those objectives that apply to the UXO problem are as follows:

- develop investigation methods and technologies that are capable of locating and characterizing UXO in a timely, cost effective, and quality manner

- develop innovative, compliant technologies that reduce remediation costs for sites containing UXO

- facilitate transfer of those UXO-related technologies to field use. This includes, but is not limited to encouraging the use of the Standardized UXO Test Sites developed under SERDP and ESTCP funding

- develop risk-based modeling and simulation methods for hazard assessment and establishing remediation priorities and scientifically defensible "no further action" decision points for UXO-contaminated land

UXO Program

UXO

FY 2001	
12	Total projects
8	Completed projects

FY 2002	
12	Total projects
8	New Start projects*

* Does not include projects to be funded under the FY 2002 Supplemental Solicitation.

For FY 2001, the UXO Technology Thrust Area received approximately 4 percent of the SERDP budget. In FY 2001, SERDP conducted three solicitations that requested project proposals in the UXO Thrust Area. Late in FY 2001, the supplemental solicitation (mentioned previously) with FY 2002 funding issued two UXO SONs. Due to the late timeframe, new projects from this solicitation could not be included in this Report. The two SONs from the supplemental solicitation are briefly described below. All SONs are described in detail in Appendix F.

The objective of the first FY 2002 Supplemental Solicitation SON, entitled **Advanced Approaches to Unexploded Ordnance (UXO) Detection, Discrimination, and Remediation,** is to develop technologies that will provide new solutions to the diverse problems of UXO-contaminated land sites. Advances are needed in all aspects of the procedures for the detection, discrimination and remediation of UXO. A second FY 2002 Supplemental Solicitation SON, entitled **Unexploded Ordnance (UXO) Site Characterization and Remediation Technologies for Underwater Sites,** seeks to develop technologies to support characterization and/or clearance actions for UXO found on underwater sites. Research and development proposals should focus on one or more of the following activities:

- Novel engineering-based techniques/platforms that overcome the access limitations for locating UXO present in underwater.

- Improved signal processing and or sensors to aid in discrimination of debris/clutter from targets in underwater UXO-contaminated areas.

- Mechanical or other methods to aid in the cost effective and safe direct clearance of underwater UXO-contaminated sites; these may include render-safe technologies.

The following list reflects projects completed in FY 2001, and projects continuing into FY 2002. Also included are titles of projects that begin in FY 2002. Complete descriptions of all of the projects for FY 2001 and FY 2002 may be found in Appendix E - UXO Project Summaries.

Subthrust: *Improved UXO Site Characterization and Sensor/ Platform Development*

Subthrust: *Develop Innovative Data Processing/Fusion for UXO Discrimination*

Subthrust: *Tools to Aid in the Cost-Effective Removal and Disposal of UXO*

FY 2001 Completed Projects
None

FY 2002 Continuing Projects
None

FY 2002 New Start Projects
None

FY 2003 UXO Initiatives

Based on the large allocation of late FY 2002 funds to the SERDP UXO Thrust Area, SERDP decided to limit the solicitation for FY 2003 to accommodate the startup of the new projects under the FY 2002 Supplemental Solicitation. Therefore, the only FY 2003 SEED SON solicitation intends to fund research in pursuit of **Innovative Approaches to UXO Cleanup**. These SEED projects should seek to develop proof of principle for new sensors, explore new discrimination techniques, or illustrate new render-safe or removal technologies, or technologies that support such efforts through improvements in navigation, geo-location, or ground or airborne vehicle technologies. Advances are needed in all aspects of the procedures for the detection, discrimination and rendering safe of UXO. Items ranging from 20-mm shells to 2000-lb bombs must be detected and discriminated from other non-hazardous items in the subsurface. Algorithms are needed that can exploit data from current state of the art sensors and advanced sensors that are now becoming available. This must be done in a variety of environments, using a variety of supporting vehicle and navigation technologies.

Detailed descriptions of the FY 2003 UXO Statements of Need may be found in Appendix F.

APPENDIX A
Cleanup Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Aquifer Restoration by Enhanced Source Removal; CU-368

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Carl Enfield; U.S. Environmental Protection Agency, National Risk Management Research Lab – Cincinnati, OH

FY 2001 COMPLETED PROJECT

DESCRIPTION: Contaminants such as low-solubility organics (i.e., chlorinated solvents) have migrated through the subsurface and entered groundwater at more than 1,000 Department of Defense (DoD) sites. At these sites, the organic contaminants are found in one of four phases: (1) volatilized within the soil's vadose zone (vapor phase), (2) dissolved in the groundwater (dissolved phase), (3) sorbed to the aquifer solids (sorbed phase), or (4) as a separate non-aqueous phase liquid (NAPL) phase. All of these phases contribute to groundwater contamination. Conventional cleanup approaches entail pumping groundwater out of the contaminated soils and treating the groundwater aboveground. Unfortunately, because of the low solubility of the contaminants in water, they tend to remain in the soils regardless of the amount of groundwater that is pumped from the site. Improved removal technologies are greatly needed to effectively clean up soil and groundwater contamination resulting from the release of chlorinated solvents.

The objective of this research was to evaluate five different Enhanced Source Removal (ESR) technologies (cosolvent solubilization, cosolvent mobilization, macromolecular solubilization, surfactant solubilization, and air sparging/soil vapor extraction) for their effectiveness at removing the sorbed contaminants in the source zone. These technologies were tested in controlled release, highly instrumented test cells at the Groundwater Remediation Field Laboratory (GRFL) at Dover Air Force Base, Delaware. The test cells allowed perchloroethylene (PCE) to be injected into an undisturbed geologic setting as the test constituent. The work involved a series of demonstrations supported by site characterization and laboratory research required to produce credible field demonstrations and evaluations. The work focused on remediation of source areas of sites believed to be contaminated by NAPLs at residual concentration (no longer mobile and, therefore, not readily available for extraction by pumping). Each technology was compared to one or more alternative remediation technologies including conventional pump-and-treat as a reference treatment system. Results of these comparisons showed the differential improvement achieved by one process relative to another.

BENEFIT: Development of effective in-situ approaches to remove source zone chlorinated solvent contamination will reduce greatly the length of time needed to treat the associated dissolved phase plumes and hence reduce the cost of groundwater remediation for the DoD and other Federal agencies.

ACCOMPLISHMENTS: Three dense non-aqueous phase liquid (DNAPL) enhanced extraction technologies (cosolvent solubilization, air sparging/soil vapor extraction, and surfactant solubilization) have been demonstrated at the Dover AFB National Test Site. Approximately two-thirds of the DNAPL was extracted with each of these technologies. In addition, the DNAPL release and pre-demonstration tracer tests have been completed in preparation for evaluation of macromolecular solubilization. A statistically based Lagragian model has been developed and used to forecast performance of source remediation technologies. The model projections were compared to measured field performance. A website (http://hillafb.hgl.com) has been established to aid in public dissemination of the results.

TRANSITION: The results of these comparisons between alternative remediation technologies will be compiled into a manual. This manual will be prepared for the user community to facilitate design of these systems. The design manual will contain anticipated system performance and will be made widely available to facilitate transition of the technology developed.

PROJECT SUMMARY

PROJECT TITLE & ID: Federal Integrated Biotreatment Research Consortium (FIBRC): Flask to Field Initiative; CU-720

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Danny Averett; U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory – Vicksburg, MS

FY 2001 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop a set of "realistic" biotreatment processes for the cleanup of several classes of contaminants at Department of Defense (DoD) sites. All treatment processes have technical and economic limitations, and part of the experimental process of this program was to define these limitations. The technical approach was to investigate a variety of promising biotreatment processes at the bench- and intermediate-scale. The experiments in this program were directed toward four major contaminant areas: (1) explosives, (2) chlorinated solvents, (3) polychlorinated biphenyls (PCB), and (4) polycyclic aromatic hydrocarbons (PAH). In some cases, the concepts under investigation were developed by members of this consortium. In other cases, concepts that indicate promise were taken from current literature and professional affiliation. The processes under development have the potential to be fielded within a reasonable amount of time. This approach ensured that the DoD will have more cost-effective remediation technology within a time frame required for DoD site remediation activities. Biotreatment processes were evaluated for the following four major contaminant groups:

- ***Explosives Contaminated Soils And Groundwaters.*** A variety of promising biotreatment techniques were investigated for remediation of soil and groundwater contaminated with explosives compounds. Explosives contamination represents one of the most prevalent types of organic contamination within the DoD. The research projects in this thrust area were: (a) Discovery of Novel Enzymatic Reactions and Determination of Biodegradation Mechanisms and Pathways and (b) Chemical Transformation followed by Biotreatment for Treatment of TNT Contaminated Groundwater.

- ***PAH Contaminated Soils.*** This class of contaminants represents one of the most regulated due to their carcinogenic properties. Also, because of their large and complex molecular structures, they also represent some of the most difficult of all contaminants to biologically degrade. The research projects in this thrust area were: (a) Management of Bioremediation of Soils Contaminated with Heavy Molecular Weight PAHs (hPAH) through Bioaugmentation and Bioavailability Enhancement and (b) Intermittently Mixed Reactor System for Enhancement of Mass Transfer and Bioavailability in the In-Situ Treatment of hPAH-Contaminated Soils.

- ***Chlorinated Solvent Contaminated Soils and Groundwaters.*** Chlorinated solvents represent a class of contaminants that is detected at more DoD sites than any other contaminant group. The research projects in this thrust area were: (a) Electrically-induced In-Situ Reductive Dechlorination of Chlorinated Solvents and (b) In-Situ Solvent-Extraction-Residual-Biotreatment of Chlorinated Solvents.

- ***PCB Contaminated Soils.*** Soils contaminated with PCBs represent one of the most challenging compound groups under investigation in this project. PCBs are found at many DoD installations due to improper disposal of hydraulic fluids and waste lubricating oils. The research project in this thrust area was: Enhancing PCB Biodegradation.

BENEFIT: The primary benefit of this study is reduced remediation costs associated with development of "realistic" biotreatment processes for the cleanup of contaminated DoD sites. Secondary benefits include: expanded implementation potential of existing and developing biotreatment processes, biotreatment technologies that result in the on-site destruction of contaminants, and increased regulatory and user acceptance.

ACCOMPLISHMENTS: With the PCB pilot study drawing to a close, work to compile the results from each of the four major contaminant groups ensued. It was decided that a one volume report would be written to include reports on all contaminant groups and a general summary. Three hard copies and an electronic copy of the final draft report were submitted to SERDP.

TRANSITION: This project will develop for the DoD community a biotreatment "toolbox" that can be drawn upon to offer the right process for each site. The technologies produced by this project are intended to serve remediation project managers who want options and well defined limitations of each option made available to them during their remediation process selection. Each process, whether it is traditional or innovative, has technical limitations and risks associated with its fielding. The knowledge of these process limitations will be required to reduce the risks accepted by the installation and regulatory agencies to an acceptable level.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program– McClellan AFB, CA; CU-861

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Don Gronstal; McClellan Air Force Base – Sacramento, CA

FY 2002 FUNDS: $340K

DESCRIPTION: The National Environmental Technology Test Site (NETTS) program goal is to enable efficient demonstration of innovative detection, monitoring or remediation technologies, either on an individual basis or in parallel with similar projects, under representative hydrological and climate regimes as found at many contaminated sites in the Department of Defense (DoD). Current environmental cleanup technologies are costly, slow, and largely ineffective. The NETTS program provides test beds for research to fully understand the mechanisms in proposed treatment processes. The NETTS National Test Location at McClellan Air Force Base (AFB) provides test sites to investigate technologies primarily for treatment of unsaturated soils and extracted soil-gas contaminated with chlorinated solvents, as well as ex-situ treatment of contaminated groundwater.

As a NETTS test location, McClellan AFB provides a well-characterized demonstration site for applied research, demonstration, and evaluation of promising remediation and monitoring technologies. McClellan AFB currently has twenty operational soil vapor extraction (SVE) systems. All systems have dedicated utilities adjacent to them allowing for convenient slip-stream demonstrations. McClellan AFB's groundwater treatment plant currently services 53 extraction wells. There is an additional groundwater pretreatment system with 7 extraction wells. The SVE systems and groundwater treatment facility provide opportunities for demonstrating in-situ and ex-situ techniques for remediating soils and groundwater contaminated with solvents. There are more than 400 groundwater monitoring wells located on and around McClellan AFB.

BENEFIT: Test locations are fully characterized. The NETTS test locations help save time and money for technology demonstrators by providing on-site management, pre-characterization, and timely permitting. An established, dedicated test site enables technology demonstrations to be performed at a cost lower than that of a one-time demonstration elsewhere.

ACCOMPLISHMENTS: In FY 2001, the McClellan AFB NETTS location accomplished the following: issued four final work plans for projects, provided support to principal investigators (PIs) for Work Plan development for seven projects, provided support to PIs for Technology Application Analysis Report preparations for two field completions, provided infrastructure and Regulatory Compliance support to thirteen on-going and new start projects, and completed construction of a Soils Treatment Facility. McClellan AFB has been host to both DoD and non-DoD funded technology demonstrations. Information on demonstrations can be found at http://www.afbca.hq.af.mil/mcclellanem.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program – Naval Base Ventura County, Port Hueneme, CA; CU-863

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Ernest Lory; Naval Facilities Engineering Service Center – Port Hueneme, CA

FY 2002 FUNDS: $750K

DESCRIPTION: The objective of the Naval Base Ventura County (NBVC) National Environmental Technology Test Sites (NETTS) National Test Location (NTL) at Port Hueneme, CA, is to support demonstration of technologies for characterizing and remediating soil, sediments, and groundwater contaminated with fuel hydrocarbons, waste oil, and fuel additives such as methyl tert butyl ether (MTBE). It provides test sites to investigate both ex-situ technologies for treatment of soils and in-situ technologies for groundwater. The Test Location Manager (TLM) at NBVC, Port Hueneme provides programmatic, infrastructure and technical support to researchers for characterization and remediation demonstrations. Programmatic support includes integration of the following: (1) Quality Assurance/Quality Control (QA/QC) procedures, (2) test protocol guidance, (3) demonstration reporting format, and (4) environmental setting, cost-and-performance data retrieval guidance. Infrastructure and its management (operation and maintenance) include: (1) monitoring wells, (2) in-line sensor network, (3) ex-situ treatment facility with hazardous material handling capability, (4) utilities, and (5) contaminated soil, sediments and groundwater resources. Technical support will include: (1) characterizing and monitoring contaminants, (2) processing permits, (3) supporting stakeholder involvement, and (4) transferring technologies.

BENEFIT: The NTL for fuel hydrocarbon and waste oil provides well characterized test locations, controlled field conditions for comparative evaluations of technologies, uniform evaluation criteria for demonstrations, reporting of results and technology transfer, and cost savings through amortization of infrastructure and management.

ACCOMPLISHMENTS: In FY01, the Port Hueneme NETTS site supported three EPA evaluations: (1) propane biostimulation (Envirogen, ESTCP funded), (2) high energy electron injection (Hadley & Aldrich) and (3) HiPOx (Applied Process). The following tasks were conducted or are currently being supported by NETTS team members: (1) reviewed and commented on work plan and quality assurance project plan, (2) involved in two extraction well and system installations, (3) supported permit application documentation preparation, (4) maintained the two extraction systems, (5) maintained Environgen/EPA tracer and gas injection systems, (6) supported sampling events for permit requirements, and (7) involved in sampling events for the ESTCP Long-Term Monitoring project. Ninety extraction and injection wells associated with the tracer system at the natural attenuation site were decommissioned.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full-scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: National Environmental Technology Test Sites (NETTS) Program – Dover AFB, DE; CU-866

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Tim McHale; Air Force Research Laboratory – Dover AFB, DE

FY 2002 FUNDS: $567K

DESCRIPTION: This National Environmental Technology Test Sites (NETTS) National Test Location at Dover AFB, which is managed by the Air Force Research Laboratory, provides test sites for the application of characterization and remediation technologies for soil and water contaminated by chlorinated solvents. Its centerpiece is the Groundwater Remediation Field Laboratory (GRFL). The GRFL consists of isolated, well-monitored, in-situ controlled release test cells, in which mass-balance studies of the fate, transport and remediation of dense non-aqueous phase liquids (DNAPL) may be performed. Operations consist of long-term compliance monitoring of the site and infrastructure maintenance, as well as project support to include among other things injection and monitoring of the test constituents (primarily trichloroethylene and perchloroethylene), demonstration of innovative technologies, some analytical support to demonstrators, and management and disposal of a minimal amount of waste from the tests. The process for obtaining permits for contained releases is established. In addition to supporting the contained release test cells and accompanying infrastructure, several demonstrations located in existing plumes on Dover AFB are given significant field and laboratory support, as well as coordination of activities and permitting as required by State, Federal, and local regulations. More recently, the Dover NETTS site has undertaken research initiatives to address concerns over a methyl tert-butyl ether (MTBE) plume that is migrating towards the Base boundary. A biodegradation study funded by the National Science Foundation will be performed.

BENEFIT: The GRFL is a unique resource, the primary purpose of which is to provide contained release cells for DNAPL research and development that avoid making the gross assumptions that would be necessary if experiments were conducted in previously contaminated aquifers. DNAPLs are immiscible with and denser than water, and when spilled on the ground, migrate below the water table. Once below the water table, they are difficult to locate and remove.

ACCOMPLISHMENTS: In FY01, the Dover NETTS site provided support to twelve ongoing projects, conducted detailed characterization of the MTBE plume in support of new projects, recruited a new MTBE project (Envirogen/NSF), installed wells in support of four projects, collected soil and groundwater samples for numerous lab and field studies, analyzed over 300 groundwater samples in support of USGS/Dover AFB investigations, developed cooperative efforts between USGS, Dover AFB, and Dover NETTS, attended Test Location Manager (TLM), Remediation Technologies Development Forum (RTDF), and Federal Remediation Technologies Roundtable (FRTR) meetings, presented at the EPA/State/DoD Regional Environmental Colloquium and USGS/DoD (DODEC) conference in Charleston, SC, and submitted an application for a new permit. A DNTS web site (http://www.dnts.org/) and interactive CD have been developed.

TRANSITION: This project will continue to support the transition of technology as defined by the NETTS Mission Statement that reads: Provide accessible, well-supported field locations for proof-of-principle, applied research, and comparative demonstrations and to facilitate transfer of innovative environmental technologies from research to full scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: Bioenhanced In-Well Vapor Stripping to Treat Trichloroethylene; CU-1064

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Perry McCarty; Stanford University – Stanford, CA

FY 2001 COMPLETED PROJECT

DESCRIPTION: The objective of this project is to demonstrate the potential of combining two innovative, remediation technologies, in-well vapor stripping and in-situ aerobic cometabolic bioremediation, to remediate an area contaminated with separate phase dense non-aqueous phase liquid (DNAPL). This hybrid treatment system will be installed and tested at a chlorinated solvent contamination site at Edwards Air Force Base, CA. Initial operation and testing consisted of turning on the biotreatment well pump and the in-well vapor stripper blower to effect water flow through the system. Flow through the in-well vapor stripper was determined using a tracer. Groundwater levels were monitored using the monitoring wells and the pressure transducers located at the bottom and top of the treatment wells. A bromide tracer (50 mg/L) was added at the chemical addition port of the biotreatment wells. Use of a tracer provided an understanding of the system's hydraulics and allowed verification of the modeling results. The initial operational testing also measured pH, dissolved oxygen and trichloroethylene (TCE) levels in the system. Based on dissolved oxygen levels at the inlet to the biotreatment well, the amount of oxygen added in the well to support the aerobic cometabolism was calculated. Finally, as part of the initial operation phase, toluene was introduced in a single pulse in the biotreatment wells and then the system was shut off. This step was used to allow a toluene degrading consortium of bacteria to grow in the bioactive zones, as well as to demonstrate that toluene will be degraded.

During full-scale system operation, the system will be operated for three months to evaluate performance in TCE source removal. It will then be shut down for three months to observe rebound of TCE into the aquifer in order to determine where the TCE source is located and its speed and extent of dissolution. The system will be operated a second time and again rebound will be observed. An optimization strategy will be developed based upon data collected and modeling results, and system operation and rebound will be conducted a final time to determine overall effectiveness in TCE source (DNAPL) removal.

BENEFIT: The most obvious benefit is that this combination of technologies offers the potential of reducing in-situ contaminant concentrations over three orders of magnitude. The fact that the technologies are applied in-situ minimizes risk to human and environmental receptors, as well as reduces the costs of pumping water to the surface, treating it, and disposing of it. The technologies can be used at sites with any volatile, separate-phase contaminant that is susceptible to bioremediation by aerobic cometabolism.

ACCOMPLISHMENTS: Site characterization studies defined the geophysical parameters of the Edwards AFB site. Modeling studies helped in designing the treatment system. Site construction commenced with the installation of treatment and monitoring wells. After extensive system testing, in-well vapor stripping was begun and is removing 95% of TCE passing through. The biotreatment wells were then initiated and have been operating effectively for two months, removing a minimum of 65% TCE, with removals increasing. The system will be operated for an additional month before the first shut down to observe rebound.

TRANSITION: If successful at Edwards AFB, this project will transition to a full scale application that combines the two remediation technologies, in-well vapor stripping and in-situ aerobic cometabolic bioremediation, to cleanup an area contaminated with separate phase (DNAPL) and dissolved phase TCE.

PROJECT SUMMARY

PROJECT TITLE & ID: Negative Ion Sensors for Real-Time Downhole DNAPLs Detection; CU-1089

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Gregory Gillispie; Dakota Technologies, Inc. – Fargo, ND

FY 2001 COMPLETED PROJECT

DESCRIPTION: Location of dense non-aqueous phase liquid (DNAPL) sources and reliable estimates of their masses are crucial for cost-effective cleanup. No currently available method can accurately and efficiently define the subsurface distribution of chlorinated solvent DNAPLs. The objective of this project was to develop a Site Characterization and Analysis Penetrometer System (SCAPS) probe which can detect, locate, and quantify the subsurface distribution of DNAPLs in the soil. The key probe elements are a heated membrane interface and a sensitive, fast-responding downhole detector. Performance objectives were established as follows: sensor responsiveness to all common organochlorine compounds, vapor limit of detection of 1 ppmv, selectivity better than 5000:1 relative to fuel hydrocarbons, less than 3 second response time, and automatic operation as the probe is advanced by a cone penetrometer or Geoprobe.

The research objectives were to characterize the existing polytetrafluoroethylene (PTFE) membrane's time-and temperature-dependent permeability for chlorinated solvents, fuel hydrocarbons, water, and oxygen; identify, select, and evaluate promising alternative membrane materials; find the material transfer efficiency as a function of distance from the membrane, soil type, temperature, and moisture; and optimize sensor performance, reliability, and ease of operation. Three sensor approaches which exploit the high electronegativity of chlorinated compounds were identified. They were thermionic ionization sources, a photoemissive electron capture detector (PE-ECD), and a photoemissive ion mobility spectrometer (PE-IMS). The former two were investigated in this effort. Risk is relatively low because the heated membrane is already in commercial use and preliminary laboratory data have been acquired for the sensors.

BENEFIT: Annual costs greater than $500K for containment and monitoring a single DNAPL plume are typical. If successful, the sensors developed in this project will provide more cost-effect remediation owing to improved spatial resolution for delineation of DNAPLs source terms, lower sensor acquisition and operating costs, and sensor compatibility with other chemical and physical sensors. Subsidiary benefits include an improved membrane interface for all types of volatile organic compound (VOC) analysis (uphole or downhole).

ACCOMPLISHMENTS: In FY01, the Halogen Specific Detector (XSD) and Photoionization Detector (PID) sensor were successfully transitioned to the ESTCP program. Two final issues, material selection for construction of the detector and control of temperature fluctuations, were resolved in preparation for the transition of the XSD. The XSD was then tested at the site of a former dry cleaning establishment that had been cited as a source for a major perchloroethylene (PCE) contaminant plume. The PID was tested at three field locations. At a dry cleaning site, the XSD displayed marked oscillations in the signal between 11 and 19 ft and the PID mimicked these oscillations on the first push. It was hypothesized that, since these oscillations directly corresponded with oscillations in the Membrane Interface Probe (MIP) temperature, the relatively high-boiling point PCE was being trapped on the membrane and only came across efficiently at higher temperatures. In contrast to the XSD, which displayed an oscillatory signal that tracked with MIP temperature, the PID signal on another push was not oscillatory and in fact, many times the signal was increasing while the MIP temperature was decreasing. It appeared the hypothesis about the relationship between MIP temperature and oscillatory signals was proven.

TRANSITION: The project intends to transition through to the Environmental Security Technology Certification Program (ESTCP) for a full scale demonstration/validation in cooperation with Air Force Center for Environmental Excellence (AFCEE) and Environmental Protection Agency (EPA)-Ada, OK. The researchers also have identified the potential for licencing the sensor technology through a third party.

PROJECT SUMMARY

PROJECT TITLE & ID: An Innovative Passive Barrier System Using Membrane-Delivered Hydrogen Gas for the Bioremediation of Chlorinated Aliphatic Compounds; CU-1124

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Michael Semmens; University of Minnesota – Minneapolis, MN

FY 2002 FUNDS: $205K

DESCRIPTION: The objective of this project is to examine the gas transfer behavior and performance of hollow fiber membrane curtains that are installed as passive barriers. Research will assess the suitability and effectiveness of the membrane for delivering hydrogen (H_2) to accelerate the in-situ remediation of chlorinated organic compounds like trichloroethene (TCE) and perchloroethene (PCE). Membranes will be investigated in a systematic way to determine what factors control the overall remediation process. These tasks include: (1) gas dissolution behavior of membranes, (2) impact of gas composition changes and condensation, (3) impact of biofilm growth on gas transfer, (4) evaluation of solvent transformation, (5) mathematical model development, and (6) pilot reactor studies.

BENEFIT: The overall goal of this research is to develop an innovative passive barrier remediation technology that will reduce the costs and risks associated with contaminated site cleanup. H_2 appears to be an effective electron donor for the biodegradation of halogenated aliphatics when it is sufficiently bioavailable. However, it is difficult to provide sufficient H_2 to organisms due to its low solubility. Gas permeable membranes, used as a passive treatment barrier, could be used to provide H_2 as an electron donor for in-situ bioremediation. The technical feasibility of using membranes for H_2 delivery to contaminated groundwaters will be addressed. In addition, the engineering data required to complete a cost analysis and transition the membrane-module remediation system into field scale application will be generated.

ACCOMPLISHMENTS: Clean water gas transfer studies are complete. A dimensionless correlation was developed to describe gas transfer out of the hollow-fiber membrane under creeping-flow conditions. A model for predicting changes in gas composition along the fiber with time has been developed and verified. Condensation studies are currently being designed for both sealed-end and flow-through membranes. Inorganic fouling experiments have been performed to assess the fouling impact of iron sulfide (FeS) precipitates. The dimensionless gas-transfer correlation developed for creeping-flow during clean-water experiments was used to evaluate whether FeS fouling would impair membrane performance at low aqueous flow rates. The experimental results suggest that, even under highly fouled conditions, the liquid film resistance would still control gas transfer. Biological fouling experiments are underway. A one-year column study was performed to determine if membrane-fed H_2 could stimulate PCE dechlorination under simulated aquifer conditions. Results demonstrated that, despite significant methane production, PCE dechlorination to vinyl chloride and ethene was greater in the H_2-fed column than in the control column. In this experiment membrane fouling occurred, which stopped gas transfer. Composition analyses of the foulant indicated large amounts of calcium, phosphorus, carbon, and oxygen in the coatings. Although FeS precipitate was expected, the quantities of Fe and S present were low. The membranes used in the experiment were quite fragile and ill-suited to field installation. A second column study will begin shortly with a more robust silicone-coated membrane and aquifer material from a TCE-contaminated site. A one-dimensional transient-state finite-differences computer model has been developed to investigate different H_2-addition techniques. An additional model, to be verified in the laboratory for both a reactive and conservative solute, is being developed to investigate the impact of groundwater recirculation wells on the H_2 zone of influence.

TRANSITION: The project intends to transition to the user community including, Porous Media, Minntech Corp. and Membran Corp. The project intends to select a site within DoD for field demonstration/validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Influence of Groundwater Constituents on Longevity of Iron-Based Permeable Barriers; CU-1125

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. A. Lynn Roberts; The Johns Hopkins University – Baltimore, MD

FY 2001 COMPLETED PROJECT

DESCRIPTION: This project investigated factors which may limit the longevity of iron-based permeable barriers used for in-situ treatment of organic- or metal-contaminated groundwaters. This was accomplished by examining the long-term performance of laboratory columns packed with a porous medium containing zero-valent metal solids through which simulated groundwater of differing compositions is passed, by examining the influence of eluent composition and time on the evolving composition of the solid surfaces, and by monitoring the electrochemical characterization of the surfaces after varying times of exposure. Particular emphasis was placed on developing new approaches for "real-time" monitoring of changes in system performance through a novel electrochemical probe that can be installed in-situ in pilot - or full-scale applications.

The principal technical objectives were to evaluate the impact of groundwater composition on the long-term performance of zero-valent iron (Fe) barriers and to develop a prototypic electrochemical probe for monitoring reactivity changes at either the field or laboratory scale. This project intended to conduct an integrated research program to meet the following specific objectives:

- to understand the effects of groundwater chemistry on long-term barrier performance, including delineation of the impacts of chemical reactivity changes and alterations in transport properties;
- to develop an electrochemical probe that can be used to continuously assess the ongoing performance of a reactive barrier, either in laboratory columns or in-situ in the field;
- to develop a fundamental understanding of the causes of alterations in reactivity through studying its relationship to the changing composition of the iron surface;
- to incorporate the results of these studies into a set of guidelines that can be used to predict the impact of the above factors on reactive barrier performance.

BENEFIT: The major output of this work was basic research: first and foremost, an improved understanding of the impact of the aqueous chemistry on the longevity of iron, both from the perspective of "aging" and also from clogging. This project provided a fundamental understanding of important issues dictating barrier longevity, allowing improved assessment of life cycle costs. The project team used the results to design guidelines that outline reasonable "safety factors" concerning assumed permeable reactive barrier residence times as a function of design life of the barrier. Overall, the results of this work will allow better evaluation of the tradeoff between construction costs (e.g., barrier thickness) and system longevity. The understanding and tools developed through this effort will be directly relevant to users who apply permeable iron-barrier technology for treatment of chlorinated solvents or explosives at DoD/DOE sites. The electrochemical probe to be developed through this work has considerable promise for rapid implementation as a tool for monitoring reactivity changes in full-scale applications.

ACCOMPLISHMENTS: Tritiated water tracer tests were conducted to measure the spatial variability in the porewater velocity within each column, then work was curtailed on all ten columns. Prior to shutdown, extensive sampling was conducted to obtain final reaction profiles for the following aqueous chemical constituents: total carbonate, Fe(II)/FeTOT, silica, calcium, NACs, and the CHCs (TCE, TCP, daughter products). At shutdown, grains for surface analysis were extracted from multiple points in each column. Auger electron spectroscopic analyses of particles extracted from the columns continues. Analyses indicate that the interfactial composition of the iron grains differs considerably from one column to the next. Micro Raman analyses of mineral phases on the iron grains will be conducted before submission of the final report. Ex-situ electrochemistry experiments were conducted and the experimental results (open circuit potential measurements, electrochemical noise, and impedance spectroscopy) are currently being analyzed. Based on the analysis thus far, it is apparent that the technique has promise.

TRANSITION: The project intends to transition through the Environmental Security Technology Certification Program (ESTCP), Air Force Research Laboratory (AFRL), Air Force Center for Environmental Excellence (AFCEE), EnviroMetal Technologies, Inc., and the Remediation Technologies and Development Forum Permeable Barriers Working Group.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Effective Aerobic Cometabolic Systems for the In-Situ Transformation of Problematic Chlorinated Solvent Mixtures; CU-1127

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Lewis Semprini; Oregon State University – Corvallis, OR

FY 2002 FUNDS: $225K

DESCRIPTION: The goal of this research is to demonstrate the potential of using propane and butane-utilizing microorganisms to transform problematic chlorinated aliphatic hydrocarbon (CAH) mixtures. The demonstration will be aimed towards creating in-situ bioreactive passive barriers in contaminated aquifers. Oregon State University research with microorganisms stimulated on propane or butane has demonstrated the potential for transforming a broad range of CAH mixtures that have been problematic with other cometabolic substrates. Microcosm studies conducted with subsurface solids and groundwater from contaminated Department of Defense (DoD) sites, however, have shown that propane and butane-utilizers are often absent in the subsurface, or have long lag periods before effective stimulation is achieved.

The technical approach for this project will consists of four components: (1) Laboratory studies to select the bioaugmentation approach and to develop kinetic information for single substrate (propane or butane) and mixed substrate addition (propane and phenol, for example) for the transformation of CAH mixtures. (2) Exploration of molecular probe methods for tracking the added organisms in laboratory and field studies. (3) Field demonstrations to evaluate the bioaugmentation approach and to determine the effectiveness in treating problematic mixtures of 1,1,1-TCA, 1,1-DCE, and TCE using propane or butane as a single cometabolic substrate, and mixed cometabolic substrates, propane or butane with phenol or toluene, in the latter stages of the field tests. (4) Modeling evaluations of the laboratory studies and the field studies, including simulations to aid in the design of the field demonstration tests.

BENEFIT: The primary benefit from this project will be a field documented, in-situ cometabolic process that transforms problematic mixtures of CAHs. This technology will be a new in-situ application of aerobic cometabolism for complex CAH mixtures. In addition, a bioaugmentation methodology for in-situ cometabolism will be developed for possible use as a remediation alternative at sites where natural attenuation or biostimulation will not work. This technology may be used a passive process that can be applied in deep aquifers or in a stratigraphy with multiple clay lenses. Other products from this research include developing an approach for establishing effective microbial communities for in-situ cometabolic treatment, modification to the Cometabolism Transport Model, assessment of community structure changes with bioaugmentation and cometabolic transformation, and specific probe method development for propane and butane bioaugmentation cultures.

ACCOMPLISHMENTS: Molecular techniques were used to characterize the butane utilizing mixed culture that will be used for bioaugmentation and to track the culture in microcosm studies that mimic conditions of the field demonstration. A clone library analysis permitted the 16S rDNA sequencing of dominant microorganisms within the mixed culture, without the need to isolate the microorganisms as pure cultures. These sequences were used to develop rRNA probes for Fluorescent In-situ Hybridization (FISH) to track specific microorganisms in the mixed culture. The terminal restriction fragment length polymorphism (T-RFLP), a polymerase chain reaction method, was developed to evaluate microbial population dynamics in the microcosms studies, and to study the transport and fate of the bioaugmented culture in the field study. Microcosm tests were conducted prior to the initiation of the field study to evaluate butane, 1,1-dichloroethylene (1,1-DCE), and 1,1,1-trichloroethane (TCA) degradation kinetics and the fate of the bioaugmented culture. T-RFLP analysis indicated that specific microbes of the bioaugmented culture flourished in the microcosms over extended periods (100 days) of biostimulation with butane and transformation of 1,1-DCE, a contaminant that causes significant transformation product toxicity. Numerical model parameters, including expressions for microbial growth and decay, substrate and oxygen utilization, and cometabolism of dual contaminants, were determined independently in kinetic studies of the butane-utilizing culture and in microcosm studies. The model simulated well the repetitive utilization of butane and cometabolism of TCA and 1,1-DCE in the microcosms. Model simulations were then performed under the transport conditions of the field test with alternating pulses of dissolved butane and oxygen in the presence of 1,1-DCE and TCA. Complete utilization of the butane occurred within 200 hours of bioaugmentation. 1,1-DCE was much more rapidly transformed than TCA, and efficient TCA removal occurred only after 1,1-DCE and butane were decreased in concentration. The field demonstration test site at Moffett Field, CA has been instrumented to conduct tests along two parallel test legs. One leg will be used for the bioaugmentation study, and the other leg will be used to stimulate indigenous microorganisms.

TRANSITION: The project intends to transition to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Nonintrusive Characterization of Dense Nonaqueous Phase Liquids Using Short-Lived Radiotracers in Partioning Interwell Tracer Tests; CU-1128

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Phillip A. Gauglitz; Pacific Northwest National Laboratory – Richland, WA

FY 2001 COMPLETED PROJECT

DESCRIPTION: The objective of this research was to develop partitioning interwell tracer testing using short-lived radioisotopic tracers as an effective characterization technique for Dense Nonaqueous Phase Liquids (DNAPL) in the subsurface. This technique can be viewed as the next evolution in partitioning tracer testing and offers significant benefits over currently available technologies. By injecting conservative and partitioning short-lived radioisotopic tracers into the subsurface and continuously measuring their presence in monitoring wells with moveable downhole detectors, the location and amount of DNAPL can be measured to a much greater extent than can now be achieved by any other method. The technical approach was to develop the radiochemical techniques for making tagged tracers together with assembling suitable detectors. After the field prototype has been tested, the tracers and sensors were used in a field application to further develop the method. The field testing was guided by detailed fluid flow modeling, as will the interpretation of the field results. The tasks for this project were: (1) Detector and Logging System Development, (2) Tracer Selection and Radiochemistry Techniques, (3) Laboratory Testing, (4) Pre-Test Modeling and Field Test Planning, (5) Field Testing, (6) Inverse Modeling (Data Analysis), and (7) Development of a Guidance Document.

BENEFIT: The research will develop an innovative, nonintrusive radiotracer methodology for reliably detecting, quantifying, and determining the horizontal and vertical extent of non-aqueous phase liquids (NAPLs) in the subsurface environment. The desired information will be available in an easily interpretable format and will provide the ability to detect and delineate subsurface NAPLs to an extent beyond any existing technology. This information will substantially improve risk assessment, remedial system design, optimization of remedial operations, and verification for site closure. The research will lead to a cost-effective technique for more precisely locating DNAPL sources, estimating the mass, and monitoring the transport and/or reduction of the mass over time. It is anticipated that the costs to implement the developed technology will be comparable to those of conventional partitioning interwell tracer tests, with significantly more characterization information achieved.

ACCOMPLISHMENTS: Quality-control and isotopic/chemical purity issues have been addressed with regard to radiochemistry techniques. Partition coefficients for the brominated-alcohol tracer suite have been established. Production of Br-82 has been scheduled in coordination with transporation and injection times. The pre-test modeling in preparation for field deployment has been completed. System calibration and field-testing of the detector and logging system has been performed. The system was deployed, wellfield modifications carried out, and monitoring wells installed at the OU2 site. Approval from the NRC has been received, and field test is to begin shortly. Inverse modeling will be performed during data analysis following the field test. Guidance document to follow thereafter.

TRANSITION: The project intends to transition the complete package for deployment in saturated and/or unsaturated DNAPL zones within DoD sites. The technology will be deployable by site personnel or service companies. Interest has been expressed by Current Environmental Solutions, Inc. and others.

PROJECT SUMMARY

PROJECT TITLE & ID: Biological Assessment for Characterizing Contaminant Risk at the Genetic-, Individual-, and Population-Level; CU-1129

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Todd Stephen Bridges; U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory – Vicksburg, MS

FY 2002 FUNDS: $100K

DESCRIPTION: The objective of this project is to develop a suite of technically defensible assays that can be effectively used in regulatory programs to quantify the ecological risk of contaminated sediments at the molecular-, individual-, and population-level. Researchers will quantify the biological/ecological meaning of genetic responses, collected using genosensors, by way of comparison to whole-organism assessments of toxicity and modeled population-level impacts. Dose-response information will be simultaneously generated using genosensors and whole-organism bioassays for military-relevant compounds.

During the first phase of this project, (1) sediments will be spiked with single military-relevant compounds (i.e., explosives and other organics) and mixtures at a range of concentrations, (2) sediment-dwelling organisms will be exposed to these contaminated sediments, (3) the sediments and organisms will be screened for the presence of genetic markers using developed genosensors, and (4) whole-organism effects on survival, growth and reproductive endpoints will be measured. Four sediment-dwelling organisms will be used in this project that are currently being used by the Environmental Protection Agency (EPA) and the Corps to develop chronic, sublethal sediment bioassays for national regulatory programs. Impacts at the population-level will be projected using population models developed for bioassay organisms during the course of this study. During the second phase of study, the bioassay suite will be tested using naturally contaminated sediment containing even more complex mixtures of military-relevant and conventional contaminants. The comparisons made among the endpoints at each level of organization using field collected sediments ranging in degree of contamination will allow researchers to test how robust their predictions will be under a regulatory use scenario.

BENEFIT: Currently, there is a lack of defensible methods to measure and assess ecosystem responses to insults by Department of Defense (DoD) relevant contaminants. This project will provide tangible benefits to DoD cleanup efforts by reducing the driving uncertainties in the estimation of risk in MUC contaminated sediments, namely, (1) contaminant bioavailability, (2) the toxicity of MUCs, (3) the toxicity of complex MUC mixtures, and (4) extrapolating to higher order effects (e.g., population-level impacts). The methods and data generated during this project will improve DoD's capability to defensibly define risk to aquatic organisms exposed to MUCs and to set reasonable cleanup levels that are based on the potential for toxicity at multiple levels of biological organization. Given the number of contaminated DoD/DOE sites (17,000), the potential for remedial cost avoidance is considerable.

ACCOMPLISHMENTS: The relative toxicity of the major degradation products of TNT was evaluated and the additivity assumption commonly applied in risk assessment was tested for mixtures of these compounds. The lethal toxicity of TNT and three of its metabolites (TNB, 2-ADNT, 2,4-DANT) was determined. The magnitude of the lethal effects of TNT and 2-ADNT were similar and substantially greater than effects from 2,4-DANT. TNB was found to be considerably less potent than TNT in sediments; however, the two compounds were similarly toxic in water. The nature of the chemical interaction among these four nitroaromatic compounds was examined in a mixture experiment where TNT, TNB, ADNT, DANT were represented in equitoxic concentrations in each treatment. The compounds were found to interact in a manner that was less than dose additive. Similar antagonism was found to exist between lead, phenanthrene, and TNB. Polymerase chain reaction (PCR) primer sets designed for isolation of stress gene fragments from experimental animals were used to directly examine changes in gene expression by reverse transcriptase PCR.

Amplified, expressed genes from acute exposures of invertebrates have been cloned and sequenced. Gene expression profiling of TNT toxicity in *C. tentans* was initiated.

TRANSITION: The project intends to transition to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Evaluation of Performance and Longevity at DoD Permeable Reactive Barrier Sites; CU-1140

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Chuck Reeter; Naval Facilities Engineering Services Center – Port Hueneme, CA

FY 2001 COMPLETED PROJECT

DESCRIPTION: Site-specific conditions should be the ultimate factor in designing a permeable reactive barrier (PRB) remediation solution, and the site performance and compliance monitoring plan should evaluate its operating effectiveness. Because the main goal of installation cleanup is to ensure that contamination is remediated and ultimately prevented from progressing further downgradient of the site, monitoring is needed to evaluate the capture and treatment efficiency of the PRB configuration. Since all current PRBs have somewhat different design configurations, it is important to evaluate selected sites using a consistent approach. The purpose of this project and its two companion projects with the Department of Energy (DOE) and the Environmental Protection Agency (EPA) was to achieve combined Federal agency coordination in addressing these various performance and longevity issues at specific PRB sites. The DoD, EPA, and DOE projects were executed simultaneously for a leveraged effort that will achieve maximum coordination to minimize duplication and to ensure that the most cost-effective measures will be implemented. Project coordination ensured that data collected from each site are comparable, while allowing each agency to focus on its unique needs.

This project was intended to specifically focus on only the DoD sites. The EPA and DOE provided separate funding for their selected sites. Similar to the DOE and EPA projects, the DoD project approach was conducted using the following tasks: (1) Field Monitoring Survey and Site Selection, (2) Performance Sampling at Selected PRB Sites, and (3) Performance Data Evaluation.

BENEFIT: It is estimated that potentially 500 to 1,000 DoD sites could use the PRB technology. Using actual site specific data from cost analyses performed at one Navy location, the results can typically represent most DoD sites. At Naval Air Station (NAS) Moffett Field, it would cost about $9 Million (M) to remediate the site by using a full-scale PRB over a 50-year period. Conversely, it would cost about $33M over a 50-year period using the groundwater pump-and-treat method. Specifically for Moffett, over the long term, the cost savings ratio of using the PRB technology over pump-and-treat can be as much as 4 times. Overall, it is estimated that the Moffett site can save about $24M in contaminant plume remediation costs. It is reasonable to conclude that over the long term, billions of dollars could be saved at hundreds of chlorinated compound contaminated sites where the PRB technology can potentially be applied.

ACCOMPLISHMENTS: Long term accelerated column tests using groundwater from Moffett Field and Lowry AFB were completed after passing 1500 pore volumes (10-20 years of operation) through the iron. Analysis of groundwater and iron core samples from Lowry AFB and Moffett Field was completed. Hydraulic measurements at Seneca Army Depot and Lowry AFB were completed. Hydraulic and geochemical modeling simulations using field results were performed. Together with the Tri-Agency PRB Initiative members an outline for the combined summary report and guideline document was developed. The final report based on DoD sites has been submitted to SERDP/ESTCP. Results from this work have been presented at numerous conferences and scientific meetings.

TRANSITION: The project intends to transition through the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Bioreduction and Removal of Ammonium Perchlorate; CU-1162

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Coates; Southern Illinois University – Carbondale, IL

FY 2002 FUNDS: $155K

DESCRIPTION: This project will provide a better understanding of the microbiology involved in microbial perchlorate reduction and removal. The factors controlling the applicability of microorganisms to the in-situ treatment of ammonium perchlorate contamination of natural water supplies will be determined. In addition, this work will assist in the development of protocols and molecular tools required for the modeling and application of in-situ bioremediation strategies to treat perchlorate contamination in the environment.

The objectives of this project will be addressed under the following hypotheses.

Hypothesis 1. Perchlorate-reducing bacteria are ubiquitous and are indigenous in perchlorate contaminated environments. The perchlorate-reducing population in the samples will initially be enumerated by most probable number counts (MPN) with acetate as the electron donor.

Hypothesis 2. All perchlorate-reducing bacteria contain a conserved chlorite dismutase enzyme. In order to evaluate this hypothesis, the researchers will use the purified chlorite dismutase enzyme to determine the N-terminal sequence, and develop a specific molecular probe to the gene that codes for this enzyme.

Hypothesis 3. Indigenous microbial perchlorate reduction can be easily stimulated in contaminated environments. As all ClRB isolated to date are alternatively able to utilize nitrate as an electron acceptor, the addition of nitrate to the environment should result in an increase in the perchlorate-reducing microbial population.

Hypothesis 4. The stimulated perchlorate reducing population can remove perchlorate concentrations to levels significantly lower than 18 ug/L. Several of the phylogenetically diverse ClRB isolates in the projects laboratory cultures will be selected and grown individually in continuous culture in a chemostat.

Hypothesis 5. The rate of microbial perchlorate reduction will be affected by the environmental conditions. To determine the controlling factors of perchlorate reduction, samples enriched with acetate and nitrate will be used. Specific perchlorate-reducing activity will be determined in subsamples under a range of redox, pH, and temperature values, as well as ionic strength, and perchlorate concentrations to determine optimum conditions for perchlorate reduction.

Hypothesis 6. The stimulated perchlorate-reducing population will also enhance biodegradation of co-contaminating organics. Degradation of 14-C-labeled hydrocarbons by perchlorate-reducing enriched samples will be determined by monitoring 14-CO2 production over time.

BENEFIT: Results from these studies will provide a better understanding of the microbiology involved in perchlorate reduction and the factors controlling the activity of these organisms. These studies will also allow the development of a molecular probe which will be specific for all perchlorate-reducing bacteria. Such a probe can be used for predictive determinations of the success of a biological in-situ treatment process and also as a monitoring tool for intrinsic or enhanced bioremediative efforts. Finally, this study will identify the potential of a stimulated perchlorate-reducing population.

ACCOMPLISHMENTS: Samples from both alkaline and acidic perchlorate-contaminated sites contain an active perchlorate-reducing population. In contrast to neutral pH environments, molecular analyses indicate that the perchlorate-reducing populations in alkaline/acidic sites are not members of the *Dechloromonas* and *Dechlorosoma* species. Activity experiments with the Longhorn, TX samples (acidic) indicate that the indigenous ClRB population does not reduce perchlorate upon simple addition of acetate under anaerobic conditions. A new perchlorate-reducing isolate was obtained from the acidic Longhorn, TX site. This organism, strain LT-1, is a close relative of *Azoarcus* species. Similar to all other tested perchlorate-reducers, strain LT-1 contains an active chlorite dismutase enzyme. The chlorite dismutase (CD) gene from *Dechloromonas agitata* was cloned and sequenced. Partial CD gene sequences from several other ClRB have been generated; complete sequencing and design of a "universal" CD gene probe is underway. CD expression is not constitutive and the active enzyme is only present under certain environmental conditions. The presence of oxygen inhibits the expression of an active CD enzyme. Perchlorate is required for the induction of an active CD enzyme. The presence of nitrate inhibits the expression of an active CD enzyme and perchlorate reduction only in organisms that grow by nitrate reduction. Batch culture experiments with several pure cultures indicate that all perchlorate-reducers tested can remove perchlorate levels to below detection under ideal conditions. A hydrocarbon-oxidizing perchlorate-reducer, *Dechloromonas aromatica* strain RCB, was isolated and fully characterized. *D. aromatica* is the first organism of any type in pure culture that can degrade benzene in the absence of oxygen. Studies with *D. aromatica* represent the first demonstration that organic contaminant degradation can be coupled to perchlorate reduction. Three publications appeared in peer-reviewed journals, two patents (microassay for measurement of chlorite and biological anaerobic treatment of BTEX contamination) are pending, and numerous press releases were performed.

TRANSITION: All results produced during the course of this project will be published in peer reviewed journals and will be accessible to the public. Project researchers are in the process of developing a World Wide Web page devoted to ongoing research in the area of microbial perchlorate reduction in their respective laboratories. The results, tools, and techniques produced as part of this research will be documented at this site. In addition, current ongoing research on the microbiology of perchlorate reduction has resulted in 4 patent applications which have attracted the interest of several biotechnological/ bioremediation companies.

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Bioremediation of Perchlorate; CU-1163

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Paul Hatzinger; Envirogen, Inc. – Lawrenceville, NJ

FY 2001 COMPLETED PROJECT

DESCRIPTION: The discharge of contaminated effluents during the manufacture and replacement of propellants in military missiles and rockets has resulted in substantial perchlorate contamination in groundwater in several states, including California, Utah, Texas, and Nevada. The objective of this project was to develop a biological treatment technology for the in-situ remediation of perchlorate in groundwater. Individual perchlorate degrading bacteria or a mixed bacterial culture from pilot and full-scale Fluidized Bed Reactor (FBR) systems that are currently reducing perchlorate in water to non-detectable levels were isolated and used in laboratory microcosms and flow-through model aquifers together with sediments and groundwater collected from perchlorate impacted sites. Groundwater flow and reactive transport modeling were conducted to verify degradation rates derived from laboratory studies and to aid design of field-scale applications. The model aquifers were used to determine substrate (electron donor) loading rates, perchlorate reduction kinetics by natural and inoculated strains, and inhibitory concentrations of groundwater constituents such as nitrate and oxygen.

BENEFIT: This research will provide extensive information on (1) the potential for successful perchlorate remediation at subsurface sites by addition of electron donors (i.e., biostimulation); (2) the most effective electron donors to use in biostimulation efforts, and the expected concentrations and remediation kinetics achievable with these donors; (3) the possibility for successful bioaugmentation (i.e., injection of bacterial isolates) for subsurface perchlorate remediation; and (4) the probable influence of alternate electron acceptors and environmental variables on perchlorate reduction during biostimulation and/or bioaugmentation efforts. These data will provide the fundamental knowledge required for the design and implementation of pilot-scale and full-scale remediation efforts at perchlorate contaminated sites.

ACCOMPLISHMENTS: Field samples were obtained from one pristine site and four perchlorate-contaminated sites, and five perchlorate-degrading cultures were isolated (*Dechlorosoma spp.*, *Dechlorospirillum spp.*, and another unidentified). Results from the microcosm studies revealed that (1) perchlorate-reducing bacteria are widely distributed, (2) electron donor addition is a promising in-situ approach, (3) choice of electron donor is site specific with acetate and lactate being generally effective, (4) low pH and oxygen are inhibitory to perchlorate degradation, (5) nitrate and nitrite are reduced before perchlorate, (6) sulfate is reduced after perchlorate, and (7) chlorinated volatile organic compounds may influence rates of perchlorate reduction. In the model aquifer tests, mixing at the influent port was evaluated, perchlorate transport was measured, and degradation of perchlorate, nitrate, and oxygen was quantified. Conservative transport studies have been conducted, and the "first draft" kinetic model has been developed. After determining the necessary experimental data (1. relationship among terminal electron acceptors and 2. kinetic parameters), the kinetic model was incorporated into an existing reactive transport model. Column results were then simulated with the fully coupled model, and the flow model was modified to represent simple field settings. The model will be capable of simulating applicable treatment scenarios at field sites.

TRANSITION: The long-term goal of this project is to develop and demonstrate a technology that can be easily transitioned to field deployment. The most viable methods for field implementation based on the research findings and modeling results will be identified in the final report. At the conclusion of the project, ESTCP funding will be sought to demonstrate the most promising remediation strategy in a field study, an application protocol will be prepared, and Envirogen will then commercialize and license the technology.

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Bioremediation of Perchlorate-Impacted Groundwater; CU-1164

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Evan Cox; GeoSyntec Consultants Inc. – Guelph, Ontario, Canada

FY 2002 FUNDS: $25K

DESCRIPTION: Groundwater contamination related to the production, handling and use of rocket propellants such as ammonium perchlorate has been identified as a widespread problem at Department of Defense (DoD), Department of Energy (DOE) and defense contractor facilities. Few cost-effective technologies exist for the treatment of perchlorate-contaminated groundwater. Of the technologies being evaluated, in-situ bioremediation is among the most promising because it has the potential to destroy perchlorate in place rather than transferring perchlorate to another waste stream (e.g., impacted resin or brine) requiring treatment or disposal. This research program consists of: (1) laboratory microcosm studies to evaluate the ubiquity of perchlorate-degrading bacteria in groundwater at a variety of impacted DoD, DOE and defense contractor facilities, and to assess the applicability of in-situ bioremediation as a remedial technology in a variety of geochemical environments; followed by (2) small-scale field pilot testing at one of the test sites to demonstrate that perchlorate can be biodegraded under field conditions, and to generate initial design and cost data for potential technology scale-up and validation.

BENEFIT: The presence of perchlorate in drinking water supplies is a national concern that requires the timely development of robust, reliable and cost-effective treatment technologies for large volumes of groundwater. Cleanup costs for perchlorate-impacted groundwater are expected to be in the $100Ms in California alone, the cost of which may jeopardize major DoD and propulsion contractor production programs. The support of cooperative development partners such as, Aerojet General Corporation and the U.S. Navy, for this research program highlights the need for development of cost-effective and environmentally-acceptable perchlorate treatment technologies. A significant number of other federal and defense contractor facilities may benefit from the development of cost-effective in-situ remediation technologies for perchlorate-impacted groundwater. For example, the Environmental Protection Agency (EPA) has identified at least 14 facilities in California, including 7 Superfund sites, where perchlorate is present in groundwater, and where groundwater remediation is likely to be required once final groundwater standards are established. The majority of these sites are rocket manufacturers and testing facilities associated with DoD and National Aeronautics & Space Administration (NASA).

ACCOMPLISHMENTS: In FY01, laboratory evaluations (by the University of Toronto) on geochemical impacts (perchlorate-nitrate-sulfate interactions) to perchlorate reduction and joint treatment of perchlorate and chlorinated solvents were completed. Candidate sites for the field pilot test were screened, and the Aerojet test site was selected. The workplan for pilot testing was completed, and site access and regulatory issues were resolved. The pilot test system was constructed (electron donor and performance monitoring instrumentation). System operation and conservative tracer testing commenced in September 2001.

TRANSITION: Through this research program, the project team expects to develop a remediation technology ready for large-scale field demonstration (via ESTCP or similar program), validation and implementation. The early tasks of the project will contribute key knowledge improving the understanding of the ubiquity of perchlorate-degrading bacteria and the potential applicability of in-situ bioremediation for perchlorate-impacted sites. The small field pilot test will, within a relatively short timeframe, provide design and cost data so that the technology can be scaled-up, validated, and transitioned within DoD, DOE and industry for full-scale use.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Extraction Tests for Determining the Bioavailability of Metals in Soil; CU-1165

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Michael Ruby; Exponent Environmental Group – Boulder, CO

FY 2002 FUNDS: $655K

DESCRIPTION: The primary objective is to develop a suite of simple and easy-to-use extraction tests to predict human and ecological exposures to metals in soil. Such tests will provide inexpensive and rapid tools for establishing the bioavailability of metals in soils at hazardous waste sites. Soils used in the project will be characterized for metal species and soil parameters to provide a mechanistic basis for any differences in metals bioavailability among the samples. Therefore, results from the project will also provide an understanding of how various species of a metal may differ in bioavailability, and also how various soil properties may affect metals bioavailability and the stability of the measured bioavailability estimates. The project will be framed around specific metals that are cost drivers for remediation of soils at Department of Defense (DoD) sites and will focus on the most important receptors and exposure pathways for these metals. An extraction technique developed by Exponent has already been demonstrated to predict human oral exposure to lead, arsenic, and other metals in soils. A research consortium founded by Exponent is currently completing validation of this method for lead, and working on validation of the method for arsenic. This project will extend application of this technique to other metals of concern (cadmium, copper, nickel, and zinc). The results of this extraction technique should also be applicable to assessing exposures of terrestrial mammals in ecological risk assessments. The project will include an evaluation of method parameters that might be modified to better predict relative bioavailability of metals in soil in different kinds of mammals (e.g., rodents vs. ruminants). A second aspect of the project will focus on assessing dermal absorption of arsenic and cadmium from soil.

BENEFIT: The most promising simple tests for quantifying the bioavailability of metals from soil are extraction tests to measure the fraction of a metal that is soluble and available for absorption. Evaluation of metal speciation in soils by electron microprobe analysis, as well as complete characterization of soil parameters, will be used to provide mechanistic explanations for the results of the extraction tests. Once developed, these simple tests will be useful for assessing metals bioavailability during site assessment, evaluating any changes to bioavailability after remediation or restoration, and studying the long- term stability of metal species in amended soils.

ACCOMPLISHMENTS: Analyses of the databases from all branches of the military (Army, Navy, Air Force), as well as databases from the Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) and the DoD were completed, and a White Paper that summarizes the results and determines which metals in soils drive remedial decisions at DoD sites was prepared. Specific sites from which to collect soils that will serve as the substrates for bioavailability research have been identified. The team is working with researchers at the University of Florida and the University of Cincinnati to develop in vivo study protocols for cadmium and arsenic. Work continues with researchers at Texas A&M University regarding the wildlife toxicity testing to resolve technical issues of appropriate test species, and study protocols have been drafted. The current effort is focused on finalizing the study protocol and initiating testing for the mammalian species while issues regarding the appropriate methods for the study on avian species are being resolved.

TRANSITION: A suite of simple extraction tests will be available to DoD personnel for site-specific evaluation of metals bioavailability from soil at field sites and will result in more accurate exposure and risk estimates that are still protective of human health and the environment.

PROJECT SUMMARY

PROJECT TITLE & ID: Quantifying the Bioavailability of Toxic Metals in Soils; CU-1166

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Phil Jardine; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2002 FUNDS: $448K

DESCRIPTION: The objective of this project is to investigate the relative bioavailability of the toxic metals Lead (Pb), Zinc (Zn), Copper (Cu), Cadmium (Cd), Chromium (Cr), Arsenic (As), and Nickel (Ni) in soils, primarily in relation to the human health risk posed by soil ingestion which often controls the degree of cleanup required at metal-contaminated sites. Specific objectives of this investigation are to: (1) measure changes in relative bioavailability over time in a wide range of soil types which may be encountered at Department of Defense (DoD) sites; (2) develop a predictive capability to quantify toxic metal bioavailability on the basis of soil properties; and (3) investigate the fundamental relationship between molecular-level speciation and bioavailability to enhance the understanding and predictive capability of the fate of toxic metals in soil. In this research, soil-metal bioavailability will be measured with and in vitro protocol (physiologically-based extraction test with an important flow-through modification) to estimate the bioavailability of soil-bound metals in the human gastrointestinal tract. The bioavailability of Pb, Zn, Cu, Cd, Cr, As, and Ni will be measured as a function of time in metal-spiked soils with a wide range of soil properties. Analysis of soluble metals will provide insight into the ability of soils themselves to limit metal bioavailability, without regard to any unique site-specific speciation, allowing development of a multivariable linear regression model to predict soil-metal bioavailability on the basis of soil properties. This research will also feature the use of synchrotron-generated X-ray absorption spectroscopy (XAS), a powerful technique to monitor molecular-level speciation in unaltered soil samples.

BENEFIT: Results will provide site managers and risk assessors with tools to make better initial estimates of site risk and environmentally acceptable endpoints (EAE) than using the 100% relative bioavailability default value. Although site-specific data will always need to be considered in final cleanup decisions, these results can be used to prioritize sites and to justify more definitive site-specific bioavailability studies such as detailed soil speciation investigations and in vivo studies. These results will contribute to DoD's goal of mission readiness by avoiding unnecessary diversion of DoD funds for unwarranted site cleanup.

ACCOMPLISHMENTS: Initial results have indicated that the presence of soil reduces the bioavailability of Cr and As relative to the default value of 100 percent. A multiple regression technique was used to model the observed data and suggested that key soil properties controlled the bioavailability of the toxic metals. The variability in As(II) and As(V) was strongly related to the iron-oxide content, pH, and cation exchange capacity of the soil, whereas the variability in Cr(III) was controlled by the clay content and total organic and inorganic carbon in the soil. XAS confirmed that As was preferentially associated with soil iron-oxides and Cr was precipated on the solid phase as Cr(III) hydroxide, which was consistent with the modeling results.

TRANSITION: The results of this research will be transitioned to DoD cleanup activities through both broad-based information transfer and site-specific technology transfer. One of the objectives of this research is to produce a validated, peer-reviewed model to estimate soil metal bioavailability in a wide range of soils based on soil properties. Results will be made available to the public through the world-wide web, presentation at scientific meetings, and ultimately publication in refereed archival journals. These results will be extremely beneficial to risk assessors and site managers as there are currently no methods for estimating bioavailability other than intensive site-specific investigations. Results will also be transferred to specific site cleanup activities through model validation using contaminated soils from McClellan AFB.

PROJECT SUMMARY

PROJECT TITLE & ID: Aerobic and Anaerobic Transformation of cis-DCE and VC: Steps for Reliable Remediation; CU-1167

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Tiedje; Michigan State University – East Lansing, MI

FY 2002 FUNDS: $245K

DESCRIPTION: Considerable research has focused on the anaerobic transformation of perchloroethylene (PCE) and trichloroethylene (TCE), which are among the most common chlorinated solvents found in groundwater. However, relatively little is known about the types of microorganisms and specific environmental conditions associated with the dechlorination of cis-1,2-dichloroethene (cis-DCE) and vinyl chloride (VC). Recent research identified four different microbial processes that are involved in the fate of these compounds in groundwater. These processes include anaerobic chlororespiration, anaerobic energy-yielding oxidation, aerobic co-oxidation, and aerobic energy-yielding oxidation. The microbiology of each process will be characterized, and the team of researchers will evaluate each process for its potential applicability for groundwater remediation. Specifically researchers will compare (1) the different dechlorination/degradation processes for their requirements and their rates, (2) subsequently focus on the most viable process(es) or combinations thereof, (3) develop the basic physiological understanding and molecular methods for detection of the most active organisms, and (4) combine the microbial information with site geochemical and activity information to produce criteria for site specific recommendations.

BENEFIT: Ultimately, this research will identify which geochemical and microbial factors should be evaluated in determining the fate of chlorinated ethenes at a site. Natural attenuation and engineered bioremediation are often the most cost-effective corrective actions for addressing groundwater contaminated with cis-DCE and VC. By conducting additional field geochemical measurements and laboratory studies to characterize biodegradation at a site, these cost-effective remedial options can be reliably identified. The additional cost of conducting these studies, typically $30,000-40,000, is recovered by avoiding installation or long-term operation of a "pump and treat" system. In addition, information from these studies can be used in designing in-situ biostimulation processes for cis-DCE and VC degradation.

ACCOMPLISHMENTS: Aquifer materials have been collected from eight chloroethene-contaminated aquifers, and sediment material was obtained from one site. Additional samples for the evaluation of processes 4 and 5 (aerobic transformation of cis-DCE and VC) were collected from a chemical waste site and a landfill site. *Dehalococcoides sp.* strain FL2 was isolated from a defined co-culture. The organism reductively dechlorinates TCE to VC and ethene with hydrogen as the electron donor. In contrast to *D. ethenogenes*, strain FL2 grows in a defined mineral salts medium. Sediment-free, nonmethanogenic enrichment cultures that reductively dechlorinate cis-DCE and VC to ethene were obtained from microcosms. Further analysis suggested the presence of fewer than 10 different populations in both enrichment cultures. Duplicate 16S rDNA clone libraries from the VC enrichments were established. In addition, community DNA from these cultures was isolated and terminal restriction fragment length polymorphism (T-RFLP) analyses were performed. Microcosms under different treatment conditions, along with appropriate controls, have been established with all aquifer, soil, and sediment materials. All cultures showing cis-DCE or VC oxidation were transferred to fresh, defined mineral salts medium. For process 3 (metabolic reductive dechlorination), dilution-to-extinction series were established. VC-dechlorinating activity was recovered three times from the 10^{-4} dilution, and dilution to extinction series with low-melting agarose were established to obtain pure cultures of dechlorinating populations. For process 4 (anaerobic oxidation), efforts focused on establishing enrichment cultures that oxidize cis-DCE and VC under iron-, manganese-, or nitrate-reducing conditions. VC disappearance occurred in several microcosms; however, this activity was slow and was lost upon repeated transfers to fresh medium. The addition of sterilized sediment, potential substrates as carbon sources, vitamin mixtures, small amounts of yeast extract, repeated inoculation, and the addition of different forms of ferric iron had no stimulating effect on VC removal. VC removal under denitrifying conditions was observed in microcosms established with river sediment material; however, no stoichiometric relationship between nitrate removal and VC oxidation could be established. Methane was formed in most of the live microcosms along with some ethene, indicating that nitrate became limiting in the microcosms. Due to the high organic carbon content, it proved difficult to maintain a constant supply of nitrate. Secondary enrichments amended with nitrate and VC were established, and are being monitored for VC and nitrate removal. For processes 4 and 5 (co-metabolic and metabolic oxidation), all available materials were evaluated for their potential for aerobic degradation of cis-DCE and VC. Structural analogues such as ethene, ethane, or methane were used as cosubstrates to test for cometabolic oxidation. The established microcosms showed significant VC-degradation activity under aerobic conditions, but only in the presence of ethene as a cosubstrate, and VC removal without ethene was negligible. Microcosms established with materials from another site rapidly metabolized VC in the absence of cosubstrates. Transfers to fresh, defined mineral salts medium were successful, and VC degradation occurred without the addition of a cosubstrate. The aerobic degradation of cis-DCE occurred in microcosms established with aquifer material from three sites. Addition of ethene or ethane as cosubstrates resulted in enhanced cis-DCE removal rates.

TRANSITION: This project will develop a site characterization protocol for use in feasibility studies at sites contaminated by chlorinated solvents. This protocol would complement existing documents, such as the Technical Protocol for Evaluating Natural Attenuation of Chlorinated Solvents in Ground Water (EPA/600/R-98/128). A flow chart will be developed to aid the practitioner in identifying which chlorinated solvent transformation process may be relevant at a site. Rate constants of cis-DCE and VC transformation in microcosm studies will also be included to aid in modeling studies.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of the Aerobic Oxidation of cis-DCE and VC in Support of Bioremediation of Chloroethene-Contaminated Sites; CU-1168

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Gossett; Cornell University – Ithaca, NY

FY 2002 FUNDS: $287K

DESCRIPTION: The lesser chlorinated ethenes , cis-1,2-dichloroethene (cDCE) and vinyl chloride (VC), tend to accumulate at chloroethene-contaminated sites under anaerobic conditions, limiting the application of natural attenuation and enhanced reductive anaerobic in-situ treatment technologies. Aerobic degradation of lesser-chlorinated ethenes has been demonstrated; however, present understanding of the transformation potentials of cDCE and VC is limited, thus limiting the reliability of, and confidence in, natural and enhanced biological alternatives for site remediation. This project will try to determine the distribution and metabolic capabilities of microorganisms able to mineralize cDCE and/or VC in aerobic subsurface environments. Two complementary approaches will be used to locate organisms capable of growth-coupled, aerobic oxidation of cDCE and/or VC at contaminated sites: microcosm enrichments and direct isolations from site material. Once located, the organisms will be isolated and characterized. The relationships that may exist between chloroethene degraders and ethene degraders from each site will be evaluated to determine whether the chloroethene degraders were derived from the indigenous ethene degraders. Once the relationship between ethene degraders and chloroethene degraders is clear, spatial distribution of aerobic chloroethene degradation and the distribution of chloroethene-oxidizing bacteria in the field will be assessed.

BENEFIT: Results will delineate the roles of cometabolism vs. growth-coupled degradation in the natural attenuation of lesser-chlorinated ethenes. Results are thus expected to lead to improved site assessment (sites can be screened for existing and potential aerobic oxidative degradation activities); improved remedial-action decision-making (the effects of oxidative mechanisms can be better taken into account in modeling either natural attenuation or the effects of enhancement alternatives); and more reliable bioremediation technologies (enhancement strategies can be developed to take advantage of the aerobic transformation mechanisms). A better understanding of these growth-coupled, aerobic oxidative pathways should expand the number of sites judged suitable for bioremediation alternatives (natural and enhanced), with potential savings to DoD in the millions of dollars.

ACCOMPLISHMENTS: Thirty-four samples from a variety of sites considered "promising" were screened with the goal of locating and characterizing organisms capable of growth-coupled, aerobic oxidation of vinyl chloride (VC) and cis-dichloroethene (cDCE). In exactly one-half of the samples, such VC-oxidizers were found. In two samples, cDCE oxidizers were detected. Subsequently, the researchers have proceeded to characterize the isolates derived from enrichments from these site-materials. Characterization has focused on several aspects: phylogeny; pathways; ability to use alternative substrates; kinetics (particularly affinities for the chlorinated substrate and oxygen), and cross-induction.

TRANSITION: Transition will occur by the following: (1) incorporation of the aerobic, oxidative pathways into comprehensive fate- and-transport models, providing site managers with enhanced tools for decision-making; (2) incorporation of the findings into both Air Force and EPA natural- attenuation protocols for chlorinated ethenes; and (3) incorporation of the results into the ESTCP protocol for assessment of suitability for Reductive Anaerobic Biological In-Situ Treatment Technology (RABITT).

PROJECT SUMMARY

PROJECT TITLE & ID: Factors Affecting cis-DCE and VC Biological Transformation under Anaerobic Conditions; CU-1169

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Alfred Spormann; Stanford University – Stanford, CA

FY 2002 FUNDS: $243K

DESCRIPTION: The objective of this project is to establish a better understanding of aerobic and anaerobic transformation of cis-dichloroethene (cis-DCE) and vinyl chloride (VC). Most remediation approaches involve the extraction of contaminated groundwater and its cleanup at the surface through expensive physical and/or chemical methods. However, anaerobic biological processes have resulted in the natural destruction (intrinsic bioremediation) of the chlorinated solvents in some cases. Cis-DCE and VC are intermediates in the biological reductive dehalogenation of PCE and TCE. Molecular hydrogen appears to be a key electron donor for these reductive processes. However, the transformation of cis-DCE to VC, and of VC to ethene is very slow. A major question raised in such biodegradation is why the process does not go to completion to ethene. How can hydrogen most effectively be funneled towards reductive dehalogenation of cDCE and VC? How can one determine at a given site the reason for lack of complete biodegradation? Laboratory studies will be performed to better understand these questions and to develop procedures that can be used in the field for their evaluation.

BENEFIT: The expected benefits of this research are the following: (1) New basic information on the mechanism of biological reductive dehalogenation of cDCE and VC; (2) Molecular probes for reductive VC dehalogenation; (3) Test of mathematical model for growth limitation at low substrate concentrations; (4) Data on inhibition of cDCE and VC reductive dehalogenation by other co-contaminants; (5) Field procedure to determine availability of hydrogen for reductive dehalogenation; (6) New basic information on microbiology of anaerobic cDCE and VC oxidation; and (7) Simplify field procedure to measure electron donor release for simple use at field sites.

ACCOMPLISHMENTS: The gene(s) encoding the reductive VC dehalogenase have been isolated via an inverse-polymerase chain reaction approach, and their sequencing is now underway. In order to quantify the composition of the microbial community involved in reductive dehalogenation of cis-DCE, probes that are specific for each of the microbes present were developed, thereby allowing the relative abundance of the microbes during growth using Fluorescent In-situ Hybridization (FISH) to be monitored. To isolate microorganisms capable of anaerobic oxidation of VC, several enrichment cultures were begun in bicarbonate-buffered mineral media with sediments from Dover Air Force Base, DE, and Moffett Field, CA. Electron acceptors used were nitrate, amorphous ferric iron alone and with various concentrations of nitrilotriacetic acid (NTA) as complexing agent, and sulfate. In the absence of an electron acceptor other than bicarbonate, slow conversion of VC to ethylene was observed in enrichments obtained with either inoculum. After an initial lag-phase of two to three weeks, a decrease in VC-concentration was observed at a rate of 0.5 to 3 nmol/l per day. Ethylene formation in those cultures was observed at corresponding rates. Similar results were obtained from cultures amended with sulfate, however, the decrease in VC-concentration and increase in ethylene-concentration were in general lower with maximum rates of 0.3 nmol/l per day. In the presence of amorphous iron and in the absence or with only low concentrations of NTA, VC-concentrations decreased with rates in the same range as with sulfate, however, less ethylene was formed. With amorphous ferric iron and higher concentrations of NTA, the decrease in VC-concentration was in the same range as in controls inoculated with autoclaved sediment and no ethylene was detected. Cultures amended with nitrate also displayed no difference in decrease of VC-concentration as compared to sterile controls.

TRANSITION: The research that has been conducted over the past several years on reductive dehalogenation has been used by DuPont in the application of reductive dehalogenation for enhanced bioremediation of PCE and TCE at their own sites, and in conjunction with the Remediation Technology Development Forum (RTDF) studies with EPA, DOE, and DoD. The researchers have helped advise the development of enrichment cultures for bioaugmentation and on the requirements for carrying out this process. Through these cooperative studies, the results of this research will be quickly disseminated to the RTDF consortium members and others.

PROJECT SUMMARY

PROJECT TITLE & ID: Foam Delivery of Hydrogen for Enhanced Aquifer Contacting and Anaerobic Bioremediation of Chlorinated Solvents; CU-1203

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Hirasaki; Rice University – Houston, TX

FY 2002 FUNDS: $257K

DESCRIPTION: Hydrogen sparging of aquifers contaminated with chlorinated solvents has been shown to enhance microbial dechlorination in-situ. The major concern in the application of this remedial approach is the ability to distribute hydrogen effectively throughout the contaminated interval such that complete dechlorination can occur. A promising method to improve hydrogen contact throughout a contaminated interval and to greatly extend the horizontal migration of hydrogen in the subsurface is to deliver the hydrogen as an "in-situ generated foam" - a dispersion of gas in water that is stabilized from coalescence by the presence of a small amount of surfactants. The objective of this effort is to investigate the ability of hydrogen-foams to more effectively contact aquifer sands, thereby supporting rapid dechlorination activity compared to conventional hydrogen sparging. The foam is generated by injection of a slug of dilute surfactant solution into the well, followed by gas injection. The gas bubbles that form are inhibited from coalescence by the surfactant adsorbed at the interfaces, and the lamellae or "soap films" between the bubbles increase the resistance of the gas to flow through porous media. A previous field study has demonstrated that the use of foam greatly improves the extent of aquifer contacted by the injected gas.

BENEFIT: The expected benefit of hydrogen delivery as foam is increased well spacing and decreased frequency of sparging. If foam can increase the distance that hydrogen contacts the base of the aquifer from 3 feet to 15 feet, the area of the base of the aquifer contacted by hydrogen may increase by a factor of 25. Alternatively, an aquifer can be remediated with 1/25 as many wells if foam improves the aquifer contact by the amount of this illustration. If the residual hydrogen gas saturation after sparging is increased, a longer amount of time will pass before the hydrogen is depleted and sparging needs to be repeated. Thus, foam delivery of hydrogen may reduce the frequency of sparging per well. If the trapped gas saturation in the contacted region is increased from 10% to 50%, the frequency of sparging per well can then be reduced by a factor of 5. Combined with a reduced number of wells required to conduct the remediation, the frequency of sparging a well in the entire project can be reduced by a factor of 125.

ACCOMPLISHMENTS: 2-D sandpack experiments and vertical column experiments have shown increased lateral transport and increased hydrogen persistence, respectively, in the presence of foam. Several surfactants were evaluated as candidates for enhanced aquifer contacting with hydrogen bioremediation. They were screened for being benign to bioremediation, not excessively biodegraded, and capable of foaming in sand packs. The anionic surfactant CS-330 is currently the leading candidate. The fraction of a sandpack contacted by hydrogen and the residual hydrogen saturation was increased by the presence of this surfactant.

TRANSITION: The studies are designed to yield the information required for field applications. To facilitate the transition to the field, a conceptual design component has been included in the objectives. Additionally, results of the proposed work will be provided to DoD stakeholder and industrial affiliates for incorporation into ongoing cleanup projects. Site-specific design and site characterization for the use of hydrogen-based foams is beyond the scope of this project. Therefore, this project intends to transition through the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Innovative Electrochemical Injection and Mixing Strategies for Stimulation of In-Situ Bioremediation; CU-1204

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. R. Mark Bricka; U.S. Army Corps of Engineers Engineer Research & Development Center –Vicksburg, MS

FY 2001 COMPLETED PROJECT

DESCRIPTION: The objective was to demonstrate the ability of electrokinetics (EK) to transport amendments through low permeable soils in a timely fashion through a series of proof-of-concept experiments. EK assisted amendment transport should have immediate transference to the demonstration/validation phase of testing and ultimate commiseration if the pilot study is successful. This research is based on the hypothesis that: (1) single-phase or dual polarity pulse direct current (dc) electric fields can be used to engineer strategies for transporting and thereby mixing contaminants, biosimulants, and possibly bioaugmentation inoculates to enhance in-situ dechlorination of trichloroethylene (TCE) in heterogeneous aquifers and leaky aquitards; and (2) the redox environments generated by electrolysis can be engineered as reactive zones that intercept TCE and enhance the dechlorination process. Basic research was conducted to better understand the fundamental processes. Evidence was provided by evaluating additive transport and delivery rates, microbial activity and community structure under single-phase or dual polarity pulse dc fields. In addition, the TCE transformation kinetics and end products were examined under similar conditions.

BENEFIT: The immediate benefits will be to demonstrate the transport of amendments in low permeable soils. This has been a limiting factor in the successful application of many in-situ technologies. In the long-term, if successful it is anticipated that EK technologies will become an integral part of most in-situ treatment applications. EK assisted amended transport will enable current cost of clean-up technologies to be reduced thus providing a substantial cost avoidance. In addition, EK assisted amendment transport will enable in-situ technologies to be applied in low permeable soils. Currently, most in-situ approaches for low permeable soils are very costly or relatively ineffective.

ACCOMPLISHMENTS: The EK cells and system has been designed, fabricated, and installed into an operating experimental setup. Shakedown experiments have been completed and the experimental setup is functioning as designed. Bulk analysis of the soils has been completed. Tests including moisture content, Proctor density, permeability, and classification have been conducted. Experimental design and initial tests to screen various EK parameters have been completed. These initial experiments conducted under single-phase dc fields were used to narrow the number of parameters varied throughout the remainder of the first year study. The operational parameters screened were Power Control (high vs. low), Electrode Type (inactive vs. active), and Amendment Concentration (high vs. low). Initial results showed that citrate and lactate could be transported though the through the sand in less than 12 hours. One dimensional 40 cm tests are complete with excellent results for citrate and lactate. Two dimensional 40 cm heterogeneous tests with citrate and lactate are complete with excellent results.

TRANSITION: Actual data obtained from soil samples at DoD installations will be of direct interest of owners of these sites. Because the final product of this research will be a field pilot and supporting data, users and regulators will have the initial defensible data from a pilot field study necessary to approve larger field demonstrations. If this first year effort is determined to be successful, a revised follow-on proposal will be submitted for project continuation.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Permeable Reactive Barriers Using Edible Oils; CU-1205

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Borden; North Carolina State University – Raleigh, NC

FY 2002 FUNDS: $252K

DESCRIPTION: Permeable reactive barriers (PRBs) are being considered at many sites because they are expected to have much lower operation and maintenance (O&M) costs than active pumping systems. As solvents or other contaminants migrate through the barrier, the contaminants are removed or degraded, leaving uncontaminated water to emerge from the downstream side. This project will develop and evaluate an alternative barrier system for controlling the migration of chlorinated solvents. An oil-in-water emulsion will be prepared using food-grade edible oils and then injected into the contaminated aquifer in a barrier configuration using either conventional wells or Geoprobe points. As the emulsion passes through the aquifer, a portion of the oil becomes entrapped within the pores leaving a residual oil phase to support long-term reductive dehalogenation of chlorinated solvents that enter the barrier.

BENEFIT: Edible oil barriers have tremendous cost and operational advantages over competing technologies including zero valent iron barriers and anaerobic bioremediation using soluble substrates. Construction costs for zero valent iron barriers are typically in the range of $100 per square foot of barrier. In comparison, installation of a 40 ft deep by 200 ft wide edible oil barrier is estimated to cost less than $100,000 or approximately $15 per square foot of barrier. If the edible oil barrier technology can be adequately developed, this approach has the potential to significantly reduce the cost and improve the effectiveness of aquifer remediation for chlorinated solvents and a variety of other contaminants including nitrate, chromate, and oxidized radionuclides.

ACCOMPLISHMENTS: Soil permeameter experiments were conducted to identify factors that control the loss of permeability during injection of the oil-in-water emulsion. Results from the emulsion tests showed that the extent of oil transport and associated permeability changes were sensitive to (a) sorption of the surfactant to the aquifer solids and (b) oil droplet size distribution. Techniques have been developed to measure and prepare emulsions with a controlled droplet size distribution. Continuous flow column experiments are being conducted to evaluate the efficacy of the edible oil process for controlling chlorinated solvent migration and to identify critical failure modes that may limit performance in the field. Sediment for use in the biological columns was obtained from two contaminated intervals at Dover AFB - one highly contaminated with concentrations of TCE and other organic solvents and the second much less contaminated. Prior to setting up these columns, a series of preliminary experiments were first conducted including: (1) batch microcosm experiments to determine if bioaugmentation of the columns was required; (2) growth of a bioaugmentation enrichment culture; (3) short duration emulsion distribution experiments to evaluate oil transport in the columns; and (4) construction and preliminary testing of the biological columns.

TRANSITION: Results of this research will be presented at research symposia and in peer-reviewed journals and will be shared with practitioners currently using the edible oil process at field sites. Three companies are conducting demonstrations of the edible oil process at Air Force Bases around the United States. Laboratory results obtained in this project will be implemented rapidly in the field demonstrations being conducted for AFCEE. These companies are also actively marketing the edible oil process to public and private clients. As a consequence, results will be rapidly communicated to the user community.

PROJECT SUMMARY

PROJECT TITLE & ID: Low-Volume Pulsed Biosparging of Hydrogen for Bioremediation of Chlorinated Solvent Plumes; CU-1206

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Charles Newell; Groundwater Services, Inc. – Houston, TX

FY 2002 FUNDS: $166K

DESCRIPTION: As a result of their widespread use as degreasers, solvents, and dry-cleaning agents, chlorinated solvents are among the most prevalent of groundwater contaminants found at Department of Defense (DoD) sites. Laboratory studies have shown that the addition of hydrogen as an electron donor is effective in stimulating the biological reductive dechlorination of chlorinated solvents. The challenge in scaling up this technology for field applications is the effective distribution and mixture of the hydrogen with the contaminants in-situ. One promising method that has the potential to effectively mix hydrogen in contaminated groundwater is low volume pulsed hydrogen biosparging (LVPB-H_2). The objective of this project is to further develop this innovative mixing approach by answering these key questions: (1) How much hydrogen gas can be pulsed into the subsurface safely? (2) What is the effective zone of influence of an LVPB-H_2 pulse? (3) How long do residual hydrogen bubbles persist before complete dissolution? (4) What are the reductive dechlorination rates that can be achieved using LVPB-H_2? and (5) Is LVPB-H2 an effective DNAPL removal technology? Experiments will be conducted at Rice University using the 5400 gallon pilot-scale Experiment Controlled Release System (ECRS) developed by the DoD's Advanced Applied Technology Demonstration Facility (AATDF) for testing emerging remediation technologies. Use of this research apparatus will allow the project team to perform tightly controlled studies of hydrogen breakthrough, distribution, residence time, and the resulting dechlorination processes. Besides air and water sampling during the experiments, Time Domain Reflectometry (TDR) equipment will allow the project team to visualize the migration and subsequent dissolution of hydrogen gas channels through the porous media.
BENEFIT: The benefit of this work is a more fundamental understanding of hydrogen dissolution and transport in the unsaturated zone and its effectiveness in promoting reductive dechlorination of chlorinated solvent-impacted plumes. The results will allow biosparging systems to be better designed once the radius of influence, hydrogen bubble-life time, and safety issues have been studied in detail.

ACCOMPLISHMENTS: Work to date has focused on completing a detailed work plan for the experiments, preparing the ECRS tank for experimentation, and growing chlorinated solvent-degrading bacteria. Sparge wells and water distribution manifolds were fabricated and installed in the ECRS tank. The tank was then filled with fine sand in 6 inch lifts. Coarse sand was placed in the first and last foot of the tank to aid in water distribution. Copper sampling lines and TDR waveguides were installed. The ECRS tank was purged to remove fine sediment. Two bioreactors containing chlorinated solvent-degrading bacteria are currently in operation. The first bioreactor continues to function well. Ethene and vinyl chloride are the major products of PCE dechlorination. The second bioreactor (begun after the first reactor) is showing PCE dechlorination, with TCE and cis-DCE being the major products of dechlorination. Complete degradation to ethene is expected to follow shortly.

TRANSITION: Hydrogen biosparging is a simple technology that will be easy to implement at a variety of military installations. Its configuration can be tailored to site-specific requirements, making it very flexible. For example, sparge points can be installed to act as a passive barrier to plume migration or a larger array of sparging wells can be installed for active plume remediation or source zone remediation. This technology involves a minimum of equipment and personnel, significantly reducing capital, labor, training, and maintenance costs.

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Stabilization of Persistent Organic Contaminants in Marine Sediments; CU-1207

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard Luthy; Stanford University – Stanford, CA

FY 2002 FUNDS: $500K

DESCRIPTION: The research team will investigate the feasibility for in-situ stabilization/containment of persistent hydrophobic organic compounds (HOCs) in sediments through the use of low-dose, coal-derived material, such as coke, as sorbent medial to sequester persistent organic contaminants. It is proposed that coal-derived material placed on or within sediment is a cost-effective, in-situ, non-removal, management strategy. Recent study and past research have shown that coal-derived materials are strong sorbents that may capture organic contaminants and make them unavailable in the aqueous phase and unavailable for biological uptake. Coal-derived and coaly, particulate sorbent media are two-to-three orders of magnitude more efficient in sequestering HOCs compared to natural sediment organic matter. Thus, the addition of fresh coal-derived sorbents to contaminated sediments would reduce ecosystem exposure by reducing contaminant flux between sediments, pore water, and the water column. Owing to the extreme temperatures employed during manufacture, coal-derived sorbent media like coke is free of volatile materials such as polycyclic aromatic hydrocarbons (PAHs) and is therefore not a regulatory concern. Novel whole-sample, particle-scale, and subparticle-scale techniques that have been developed for sediment characterization will be used to assess the efficacy of the stabilization technology. These techniques allow one to identify the distribution and relative availability of organic contaminants among sediment component materials. In this way, the research team can monitor how effective the coal-derived material is at capturing and binding the readily available fraction of the PAH and PCB contaminants. The team will test various low-cost materials including coke and char and compare the results with those of activated carbon. The research team will monitor the success of the stabilization process by spectroscopic and spectrometric measurements and by survival and growth of organisms currently used to develop chronic, sublethal, marine sediment bioassays for national regulatory programs. The feasibility of the technology for in-situ stabilization of PAH and polychlorinated biphenyl (PCB) contaminants found in marine sediments will be investigated.

BENEFIT: HOCs such as PAHs and PCBs are important contaminants of concern to the DoD. These contaminants associate with fine grained, organic-rich material in sediment and are long-lived. Sediment serves as a contaminant reservoir from which fish and bottom-dwelling organisms can accumulate toxic compounds like PCBs that are then passed up the food chain. Thus, cost-effective and efficient technologies for contaminated sediment management can significantly reduce the Defense expenditure on environmental restoration and achieve the DoD environmental security goals and objectives. The potential benefit of this work is the attainment of in-situ contaminant management by means of a cost-effective and non-removal technology resulting in stabilization to significantly reduce contaminant bioavailability.

ACCOMPLISHMENTS: In consideration of available information and potential impact, Hunters Point Naval Shipyard, South Basin, San Francisco Bay, was selected as an appropriate site for sediment sampling. Background, relatively uncontaminated, sediment was collected from the Baylands Nature Preserve. Preliminary toxicity and bioaccumulation studies were conducted with Hunters Point and Baylands sediment for the purpose of assessing whether sediment contacted with coal or anthracite poses increased risk with respect to toxicity, growth, or reproduction for the amphipod *Leptocheirus plumulosus* and the polychaete *Neanthes arenaceodentata*. Miroprobe laser desorption/laser ionization MS was assessed as a new technique for detection of PCBs. This work showed that the detection limit of PCBs on solid surfaces is in the range of 1-10 mg/kg. The first set of experiments involving addition of coke and anthracite to sediment was completed. Sediment form Hunters Point was classified by size and density separation into six compartments to better understand the particle-scale distribution of PCBs and PAHs. Sediment PAH and PCB analyses revealed that the light fractions of the sediment, comprising only 6% by weight of the sediment, contributes to 68% of PCBs and 80% of PAHs. Coal petrography analyses conducted on the lighter-density particles revealed the presence of wood, lignite, coal, charcoal, and char materials. Ongoing microscale analyses are evaluating the geochemical nature of particles that sorb the majority of the contaminants. To investigate the change in aqueous availability of PCBs and PAHs, desorption rate studies were conducted using Tenax resin beads with untreated and coke-treated sediment. The results indicate a reduction of PCB release due to the addition of coke. Nearly 30% of the PCBs in untreated sediment desorbed into Tenax in 15 days of contact, compared to about 10% for coke-ammended sediment for the same duration. Thus, it appears that addition of coke and contact for a month reduced the aqueous release of PCBs from sediment to 1/3 of untreated sediment. A set of 28-day sub-lethal toxicity and bioaccumulation studies by exposing two species, *L. plumulosus* and *N. arenaceodentata*, to nine experimental sediments are complete. Results from these tests showed that the addition of coke to Hunters Point sediment does not affect toxicity, growth or reproduction of these two test organisms. Protocols were developed to measure bioaccumulation using 1 L-size experiments rather than aquaria-size tests. This allows greater flexibility in assessing the affects of treatment on biological uptake. These new bioaccumulation test methods were applied to organisms exposed to the sediment samples used in the toxicity tests. The initial results show some benefit of coke addition in the reduction of PCB bioaccumulation in these organisms. Preliminary experiments with pure PCBs showed that thermal program desorption studies with PCBs in solid materials is possible. Ongoing studies are investigating the release characteristics of PCBs from several standard solid surfaces and sediment particles from Hunters Point. Three manuscripts from this work have been accepted for publication in peer-reviewed journals.

TRANSITION: Results from this research will provide a proof of concept of the proposed in-situ containment technology and a scientific basis for the support of field implementation of the technology. Successful completion of the research should lead to a future pilot scale demonstration project at a DoD marine site. Partners within this program will publish in peer-reviewed journals and will present information at national and international symposia and informal briefings at DoD, Navy, Army, USACE, and U.S. EPA offices. The results of this study will be presented in a series of USAE Waterways Experiment Station (WES) reports, utilizing a functional format to encourage demonstration and implementation beyond the proof of concept stage. The reports will include information such as process mechanisms, application protocol, process economics, technical points of contact, and process limitations.

PROJECT SUMMARY

PROJECT TITLE & ID: In-Situ Enhancement of Anaerobic Microbial Dechlorination of Polychlorinated Dibenzo-p-dioxins and Dibenzofurans in Marine and Estuarine Sediments; CU-1208

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Max Haggblom; Rutgers University – New Brunswick, NJ

FY 2002 FUNDS: $133K

DESCRIPTION: The management of marine and estuarine sediments contaminated with toxic organic compounds, including polychlorinated dibenzo-p-dioxins and dibenzofurans (PCDD/Fs), is a major problem with far-reaching economic and ecological consequences. Application of bioremediation to PCDD/F-contaminated marine and estuarine sediments is currently severely limited by the lack of fundamental knowledge about the microorganisms responsible for their degradation, including anaerobic reductive dechlorination. The research team will characterize the PCDD/F dechlorinating capability of native dehalogenating bacteria from different estuarine and marine sites. Enrichments developed from these sites and an existing dioxin-dechlorinating culture will be used to assess how PCDD/F dechlorination can be stimulated and accelerated under different terminal electron accepting conditions (methanogenic, sulfate-reducing, and iron-reducing) relevant to marine sediments. A variety of intensive amendment strategies will be tested to enhance reductive dechlorination including addition of alternative halogenated primers such as bromophenols; co-amendment with hydrogen, hydrogen donors, and other electron donors; and manipulation of the terminal electron-accepting processes.

BENEFIT: An improved fundamental understanding of dehalogenating bacterial communities that dechlorinate PCDD/Fs in marine and estuarine sediments and how these communities are affected by redox conditions and addition of primers and amendments will be gained. Data collected from enrichments and the accompanying microbial community characterization will be used for the development of conceptual and biological process models to describe and predict the effect of different enhancement methods on the terminal electron accepting process and microbial populations. These findings will result in development of methodologies for the assessment of the potential for PCDD/F dechlorination at specific sites. These methodologies could ultimately result in significant savings for costly sediment restoration projects.

ACCOMPLISHMENTS: The ability of native microbial communities to transform 1,2,3,4-tetrachlorodibenzo-p-dioxin (1,2,3,4-TCDD) was investigated in sediments from San Diego Bay, CA and Arthur Kill, NY/NJ. Various electron donors and haloprimers were examined to determine their relative effectiveness for stimulation of the dehalogenation of 1,2,3,4-TCDD. Substrates with analogous chemical structures to the dioxin, e.g. halophenols, halobenzenes, and haloanisoles, were used as cosubstrates to prime dioxin dehalogenation. Stimulation of dehalogenation was attempted under methanogenic, sulfate-reducing, and Fe (III)-reducing conditions. Dechlorination of 1,2,3,4-TCDD proceeded to a much greater extent under methanogenic conditions than under sulfate- or Fe (III)-reducing conditions. Enrichments supplied with haloprimers showed more extensive dechlorination than those without haloprimers. Furthermore, the structure of the haloprimer had a significant impact on the time required for onset of dioxin dehalogenation.

TRANSITION: This project will develop methodologies for monitoring in-situ bioremediation of contaminated sediments. The specific technologies developed will include identification of specific amendments and environmental conditions that prime and/or accelerate the dechlorination of PCDD/Fs and assessment of the potential for dechlorination at a specific site. Peer-reviewed articles and conference presentations will be used to transfer findings to the scientific community for possible future application.

PROJECT SUMMARY

PROJECT TITLE & ID: Pathway Interdiction: A System for Evaluating and Ranking Sediment Contaminant Transport Pathways in Support of In-Place Management; CU-1209

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Sabine Apitz; Space & Naval Warfare Systems – San Diego, CA

FY 2002 FUNDS: $685K

DESCRIPTION: Many of the contaminated marine sediment sites currently under investigation are in shallow, coastal areas and are much more likely than more traditionally studied offshore sediments to be impacted by advective processes such as groundwater flow, tidal pumping, wave pumping, and by resuspension via ship and storm activity. While these processes are recognized in the oceanographic community as having significance to chemical fluxes, they are largely unstudied in contaminated systems, and the relative magnitudes of these processes as compared to the traditionally assessed processes such as diffusion and bioturbation have not been determined. If contaminants are to be left in place, it is critical to evaluate potential pathways by which contaminants might pose an ecological or human health risk and to monitor, minimize, or eliminate these pathways. This effort seeks to apply an integrated suite of methods for the direct characterization of these dynamic transfer pathways for contaminants in sediments. Methods for the quantification of mechanisms, magnitudes, and directions of porewater-mediated contaminant transport will be integrated with sediment/contaminant geochemical characteristics, hydrodynamically-driven particle transport, and biological processes. While each of these processes has been examined individually, they have never been examined together such that they can be ranked and compared to support in-place sediment management.

BENEFIT: A set of diagnostic tools for characterizing and quantifying potential in-place contaminant pathways will aid in the selection, permitting and monitoring of in-situ management strategies. The payoff for a demonstrated, systematic process for measuring and evaluating contaminant transport pathways within sediment systems in support of in-place management will be twofold (1) by providing solid, measurement-based information on contaminant fate which results in the permitting of in place management, the savings can be millions of dollars per site, and (2) since pathways of contaminant transport in place can be directly measured, the ecological risk of leaving sediments in place will be reduced.

ACCOMPLISHMENTS: Several candidate sites were reviewed, based upon many project criteria, and, after a review of available data, Paleta Creek at Naval Station San Diego was selected as the Phase I site. At this site, there are a mix of contaminants of concern, including metals, polyaromatic hydrocarbons (PAHs) and pesticides. A Draft Site Design Report summarizing a large amount of data available on the Paleta Creek area has been produced. This document describes proposed sample sites, sampling matrices, analytical order and plans for data use and synthesis. Equipment development and integration has largely been completed. Prior to the field demonstration, all systems will be pre-tested at Paleta Creek.

TRANSITION: Technology transfer will proceed in a number of directions: (1) Site-specific and pathway-specific information will be disseminated via peer-reviewed journals, professional scientific and technical meetings, and technical reports, (2) All work will be carried out at sites undergoing remedial investigation or management, in direct collaboration with RPMs, regulators and stakeholders; (3) Work will be carried out in collaboration and communication with the EPA's National Risk Management Research Laboratory; (4) Dr. Apitz represents the Navy on the EPA-sponsored Remediation Technology Development Forum, Sediment Working group and the Sediment Management Work Group. Both groups seek to develop new technologies, and to provide input on sediment issues to the policy and regulatory community; (5) A technical manual or guidance document will be generated, and (6) A Conceptual Design for an Integrated

Transport Instrument will be generated. This project intends to transition through the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Determining the Bioavailability, Toxicity, and Bioaccumulation of Organic Chemicals and Metals for the Development of Eco-SSLs; CU-1210

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Roman Lanno; Ohio State University – Columbus, OH

FY 2002 FUNDS: $432K

DESCRIPTION: The goal of this research is to identify and characterize the predominant soil physical/chemical parameters that modify the bioavailability, bioaccumulation, and/or toxicity of trinitrotoluene (TNT), trimethylenenitramine (RDX), polynuclear aromatic hydrocarbons (PAH), and selected metals in soil invertebrates and plants. Exposure concentrations will be measured as total chemical levels and as the labile portion that is presumed to be bioavailable. Both of these chemical measures will be correlated with toxicity endpoints (e.g., growth, reproduction) and bioaccumulation with the ultimate goal of developing models relating soil chemistry parameters to bioavailability, bioaccumulation, and toxicity.
BENEFIT: Development of an empirical model relating soil physical/chemical characteristics to the bioavailability, bioaccumulation, and toxicity of TNT, RDX, PAHs, and selected metals to soil invertebrates and plants will allow the incorporation of bioavailability into the development of Ecological Soil Screening Levels (EcoSSLs) by facilitating estimation of bioavailable levels of chemicals from literature data where only total chemical and soil physical/chemical characteristics are presented. Current chemical methods for estimating bioavailability have been correlated with biological responses of macroinvertebrates and plants in very few studies. This research will develop these correlations, thereby validating chemical estimates of bioavailability in soils. Validation of chemical measures of bioavailability would provide another tool that can be used in early-tier screening of contaminated soils during ecological risk assessment. A large data set consistent with respect to QA/QC procedures and data criteria will be generated that can be used to develop EcoSSLs for the rapid initial screening of contaminated Department of Defense (DoD), Department of Energy (DOE), and Environmental Protection Agency (EPA) sites. This will allow the removal of low-risk sites from further ecological risk assessment and allow efforts and resources to be focused on sites that present an unacceptable risk to ecosystems.

ACCOMPLISHMENTS: Four of the five soils to be studied have been collected. The physical/chemical characteristics range from sandy, low organic carbon (OC), low pH to high OC, clay, and circumneutral pH. Studies of spiking and aging on the theoretically bioavailable fraction of chemical have been conducted with pyrene, Cd, and phenanthrene. With Cd, fast fraction partitioning was examined for three soils prepared by spiking each soil at three concentrations and subjecting to wet/dry cycles at two drying temperatures (35 and 105 degrees C). Two wet/dry cycles appeared to be sufficient in achieving a steady-state concentration, with drying temperature having no effect on the final steady-state, bioavailable concentration. With pyrene, steady state with respect to the partitioning of pyrene between the soil and the soil solution (theoretically bioavailable fraction) occurred within 2-4 days, and was maintained at that level for at least 32 days. These results were similar for three pyrene concentrations (30, 300, 1000 mg/kg) and three soil types, encompassing the extremes in soil physical/chemical characteristics. Similar tests and results have been completed for phenanthrene. Earthworm tests are currently being conducted for pyrene in two soils and collembola in three soils. Earthworm, collembola, enchytraeid, and plant tests have been conducted in one soil with RDX.

TRANSITION: Both principle investigators are involved with the U.S. EPA Steering Committee for the development of EcoSSLs and could therefore provide a direct conduit for the application of data generated during this research in the development of EcoSSLs. In turn, EcoSSLs generated with data provided from the proposed work could be used in the screening of soil contamination at DoD sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Bacterial Degradation of DNT and TNT Mixtures; CU-1212

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Rebecca Parales; University of Iowa – Iowa City, IA

FY 2002 FUNDS: $312K

DESCRIPTION: The major objective of this effort is to characterize bacterial strains with the ability to efficiently degrade mixtures of dinitrotoluene (DNT) isomers and to expand the degradative capability to include 2,4,6-trinitrotoluene (TNT). Because most contaminated sites contain mixtures of nitroarene compounds, such strains would have the potential for use in the bioremediation of field sites. This research team has isolated bacteria that can degrade both 2,4- and 2,6-DNT and will carry out physiological and genetic studies with those strains to determine whether the DNT isomers are degraded simultaneously or sequentially and how the genes encoding the pathways are regulated. The pathways, enzymes, and inducing molecules will be characterized. Team members will characterize the novel enzymes and the product(s) of TNT oxidation and screen for ring cleavage enzymes that can destroy the oxidized TNT molecule. The TNT dioxygenase and appropriate ring cleavage dioxygenases genes will be introduced into strains that degrade both isomers of DNT. The resulting strains will be tested for the ability to eliminate the toxicity of synthetic mixtures of DNT and TNT. The strains will be inoculated into microcosms containing contaminated soil from Volunteer Army Ammunition Plant and the degradation of DNT and TNT will be monitored.

BENEFIT: Bioremediation is expected to reduce the cost of remediation by $60M over previous estimates for Badger Army Ammunition Plant. Although preliminary results are encouraging, there is an urgent need to understand the regulation and degradation of mixtures. Previous experiments have revealed that 2,4-DNT could be degraded readily in soil and water from Volunteer although TNT and 2,6-DNT were problematic. The new insight about degradation of mixtures including TNT will be directly applicable to the future cleanup at Volunteer and at other TNT manufacturing sites. The research team proposes to generate recombinant organisms for the degradation of nitroarene compounds although field application of the basic discoveries to be made under this project is several years away. Cleanup of in-situ and excavated soil both in the U.S. and abroad should benefit considerably from novel microbial strategies for TNT and DNT degradation

ACCOMPLISHMENTS: New isolates appear to be much more efficient in DNT degradation than those previously studied. Polymerase chain reaction (PCR) has been used to amplify the dioxygenase alpha and beta subunit genes from four 2,6-DNT-degrading strains. The genes have been cloned and sequenced. An expression clone was constructed and whole cell biotransformations with several substrates have been carried out to determine the substrate specificity of the 2,6-DNT dioxygenase. Information obtained from gene sequencing has led to an improved understanding of the lower pathway reactions in 2,4-DNT degradation. The substrate range of nitrobenzene dioxygenase was analyzed in detail. The demonstration of oxidative transformation of aminodinitrotoluene isomers by nitrobenzene and dinitrotoluene dioxygenases is a novel discovery. The regulation of the nitrobenzene and 2-nitrotoluene dioxygenase gene clusters has been characterized. Both clusters are inducible, but the 2NTDO genes are expressed at much higher basal levels. Inducers for both systems are as follows: salicylate > anthranilate > 2-nitrotoluene > 3-nitrotoluene = 4-nitrotoluene > nitrobenzene = 2,4-DNT = 2,6-DNT.

TRANSITION: Gains achieved by the research team will be rapidly incorporated into ongoing cleanup strategies and implemented in new cleanup efforts - particularly at Badger and Volunteer. In addition, two private companies have contacted the research team to explore the feasibility for cleanup of DNT contaminated industrial sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Microbial Degradation of RDX and HMX; CU-1213

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jalal Hawari; Biotechnology Research Institute – Montreal, Quebec CANADA

FY 2002 FUNDS: $382K

DESCRIPTION: Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX) and octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX) are powerful highly energetic chemicals whose widespread use has resulted in severe soil and groundwater contamination. Efforts over the past two decades to decontaminate soil and groundwater by biological means have failed because the microbial processes and enzymes involved in degradation are poorly understood. Recently, this research team has discovered that both RDX and HMX can be mineralized under both aerobic (*P. chrysosporium* and the soil isolate *Rhodococcus sp.*) and anaerobic conditions (municipal anaerobic sludge) to nitrous oxide and carbon dioxide despite some previous reports that RDX is not mineralized under these conditions. For example, it has been demonstrated that once RDX undergoes an initial biological attack the molecule autodecomposes. The mechanism leading to mineralization is unknown; however, several testable hypotheses exist regarding how mineralization proceeds. These hypotheses will be tested by conducting fundamental laboratory experiments to identify the enzymes that cause the molecules to disintegrate and to investigate the subsequent biochemical decomposition reactions. In addition, the team will identify intermediate degradation products and study the kinetics and stoichiometry of their formation.

BENEFIT: Although this research is intended to generate the fundamental knowledge needed to understand the enzymatic processes involved in the microbial degradation of RDX and HMX, the results can be used to enhance bioremediation and facilitate future field application. When the specific degrader(s) and enzyme(s) (reductase, hydrolase or oxygenase) responsible for the initial reaction on the cyclic nitramine explosive in liquid media are discovered, it will be possible to design effective field treatment strategies. Therefore, the inclusion and the design of bench scale experiments using soil from contaminated sites will generate the necessary knowledge required for future field demonstration and application. For example, knowledge of degradation mechanisms will allow prediction and enhancement of biodegradation in the site. Insight regarding microbial and enzymatic processes together with their degradation products can be used by site managers and engineers as monitoring tools to understand the fate of explosives after removal.

ACCOMPLISHMENTS: Researchers found that by keeping RDX in nonsterile soil the energetic chemical biotransformed to its nitroso dreivatives in less than 5 weeks. Other highlights were the successful degradation of RDX when used as a nitrogen-source for *Rhodococcus sp.* strain DN22 to nitrite (NO_2^-) (30 %), nitrous oxide (N_2O) (3.2 %), ammonia (10 %) and formaldehyde (HCHO) (27 %) which later converted to carbon dioxide. Radioactivity measurements and LC-MS (ES-) analyses indicated the formation of a dead end product that contained 64 % of the original carbon content in RDX. Based on the above stoichiometry, a degradation pathway for RDX based on initial denitration followed by ring cleavage to formaldehyde and the dead end product was proposed. In another example, RDX was degraded with anaerobic sludge to produce the ring cleavage product methylenedinitramine in almost stoichiometric amounts. Methylenedinitramine is unstable in water and decomposes to N_2O and HCHO. In the presence of sludge, HCHO converted to carbon dioxide in high yield. Results obtained thus far provided insight into most of the secondary steps involved during RDX biodegradation.

TRANSITION: Successful lab-scale microcosms for the degradation of RDX and HMX can provide the basis for pilot scale up work to identify engineering parameters for field demonstration and application. Results of this project will be disseminated in such a manner as to facilitate future investigations.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Pathways of Nitroaromatic Metabolism: Hydroxylamine Formation, Reactivity, and Potential for Ring Fission for Destruction of TNT; CU-1214

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Joseph Hughes; Rice University – Houston, TX

FY 2002 FUNDS: $320K

DESCRIPTION: Independent studies conducted by members of this research team have recently converged at the discovery of a similar and novel metabolic pathway that yields products from TNT that no longer display aromatic characteristics. It should be possible to exploit this pathway in the development of improved TNT treatment methods, where the destruction of TNT is achieved and the process is carried out in-situ. The goals of this effort are to determine the biochemical mechanism of TNT ring fission and to use this fundamental information to develop strategies that harness the activity in remediation systems. Specific objectives include: (1) Identify the products of the novel TNT transformation pathway that no longer display aromatic characteristics, (2) Determine the mechanism of ring fission and identify the enzymes responsible, (3) Characterize the properties of the enzymes and their regulation, (4) Develop strategies to direct TNT metabolism to ring fission products, and (5) Validate the destruction of TNT in lab-scale microcosm testing where mass balances and toxicity reduction can be determined.

BENEFIT: Studies will yield an improved understanding of the microbial processes involved in the degradation of nitroaromatic compounds. Based on the initial work, it should be possible to develop in-situ treatment methods where the destruction of TNT is achieved. Strategies involving reduction only to the hydroxylamine level with subsequent rearrangement and ring fission would require far less carbon addition and less dramatic shifts in redox potential than conventional strategies for TNT cometabolism. The potential to drive TNT to non-aromatic end points has been demonstrated in two widely different microbial systems, and it occurs at high rates. If demonstrated that this novel metabolism can be induced and sustained in-situ, the development of low-cost remediation systems will be possible. Currently, no such technology exists for the DoD to use in the management of diffuse TNT contamination in soils.

ACCOMPLISHMENTS: Studies on the transformation of 2,4-dihydroxylamino-6-nitrotoluene (the central intermediate of TNT metabolism for *Clostridium acetobutylicum* and *Pseudomonas pseudoalcaligenes*) have confirmed that the transformation is exclusively biocatalytic under anaerobic conditions and that the transformation of subsequent metabolites continues for extended periods (over 100 days). While products again appear to be non-aromatic, attempts to use HPLC/MS have not been successful in obtaining suitable mass spectra so current studies are focusing on the derivatization of intermediates at various points in the pathway, then extracting and using GC/MS to obtain mass spectra. To study the transformation of TNT by *P. pseudoalcaligenes* strain JS765, work has focused on the ability to induce activity and avoid competing metabolic processes. A strategy was developed for growth of the biocatalyst on nitrobenzene and then feeding the nitrobenzene at a low rate during the transformation of TNT. The transformation produced not only the yellow metabolite seen previously, but also two previously unreported metabolites. A new method was developed to extract and resolve the metabolites by HPLC. The reaction was conducted at large scale and the resulting metabolites are currently being analyzed by LC MS for identification and quantitation.

TRANSITION: Laboratory microcosms will be conducted with soils from the Volunteer Army Ammunition Plant and from the Alabama Army Ammunition Plant. Results will be provided to collaborators for incorporation into ongoing cleanup projects. This project intends to transition through the Environmental Security Technology Certification Program (ESTCP) for further optimization of process parameters.

PROJECT SUMMARY

PROJECT TITLE & ID: Inexpensive Chemiresistor Sensors for Real-Time Ground Water Contamination Measurement; CU-1218 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Hughes; Sandia National Laboratories – Albuquerque, NM

FY 2001 COMPLETED PROJECT

DESCRIPTION: Sensors for organic solvent vapors are required for the detection of leaks, toxic chemicals, explosives, and solvent spills. As part of a system, these sensors need to be highly sensitive to small concentrations of vapors in the ambient air, while consuming minimal power for use in portable or remotely located devices and in long term monitoring applications. Such a sensor system must be able to quickly and reproducibly distinguish solvents from the ambient relative humidity - classifying the responses as a particular solvent, relative humidity, a mixture, or an unknown. The chemiresistor technology that this research team has developed over the last 3 years has been focused on the gas phase detection of many volatile organic compounds (VOCs). Previous experience has yielded the ability to fabricate arrays of different chemiresistors and to use the patterns of response to identify individual VOCs. The technical objective of this project was to demonstrate that the Sandia chemiresistor arrays can be packaged in such a way that they can be submerged in the aqueous phase and measure dissolved VOCs at low levels.

BENEFIT: One suggestion for advanced development would be to couple a miniature preconcentrator chip with the chemiresistor. Preliminary data in a gas phase system has shown that the preconcentrator can deliver 10 to 1000 times the signal from a given analyte depending on the preconcentration time. This would make a more expensive and complex monitoring head to be immersed in the water, but it would still be smaller than matchbox size if Sandia's micromachined preconcentrator was used. This system would also have the advantage of a means to correct for baseline drift of the chemiresistor.

ACCOMPLISHMENTS: A new chemiresistor was fabricated on a pyrex chip designed for liquid phase electrochemistry. The "waterproof" chemiresistor was used to compare sensing of xylene in water in two different ways. The first method was to insert the chemiresistor in the headspace of a water bubbler. Passing air or nitrogen through the bubbler forces the headspace vapors across the chemiresistor. Xylene is introduced into the water from the forced air stream at selected levels and is easily detected on the chemiresistor as an excess response above that from the 100% relative humidity. Levels below 1 ppm xylene in the liquid could be detected. In the second method, polluted water is pumped directly across the chemiresistor so that the liquid water washes directly across the polymer of the chemiresistor. Xylene in the water could also be detected, but long term drift due to the liquid water was experienced and would limit the lower levels of detection. Experiments were also performed with a waterproof box with the chemiresistors inside. A GoreTex membrane was used to partition the xylene out of the water with no pumping. This method works in both the headspace and "dunking" in liquid water, but gives slower responses than bubbling air through the liquid water. A new experiment for calibrating a chemiresistor in direct contact with contaminated water was designed that employed the earlier fabricated fixture for pumping water across a chemiresistor with a peristaltic pump from one liter sample bottles. The response speed of the sensor was faster than earlier results with spiked water, and is faster with higher pumping speeds. It gives the same size signal as the headspace sensor, as expected, but maintains the faster response in the headspace, probably due to the higher diffusion constant of xylene in air than in water. This confirms findings that passive sensing in the field will probably always be faster and more accurate if the sensor is in the headspace over water, or is separated from the water by a membrane.

TRANSITION: The ability to sense VOCs with the sensor head immersed in water (or other liquids) would add new capabilities for potential licensees of the multi-faceted chemiresistor technology being developed by the research team. The DoD/DOE would benefit from having an inexpensive technology for real-time monitoring of groundwater.

PROJECT SUMMARY

PROJECT TITLE & ID: Detection and Measurement of Explosives in Groundwater Using In-Situ Electrochemical Sensors; CU-1220 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Khris Olsen; Pacific Northwest National Laboratory – Richland, WA

FY 2001 COMPLETED PROJECT

DESCRIPTION: This project furthered the development of in-situ sensors for the measurement of energetic materials dissolved in groundwater. Research evaluated the scientific feasibility of applying in-situ monitoring technology for measuring TNT, HMX, Tetryl, RDX, and nitrocellulose in groundwater. The objective of the research was to develop in-situ sensors capable of replacing conventional methods (sample collection and analysis) for measuring concentrations of TNT, RDX, HMX, Tetryl, and nitrocellulose in groundwater at 20-50 ppb levels with long-term stability (years). This approach may significantly reduce the cost of long-term monitoring, can be used in existing groundwater monitoring wells, and may be compatible for installation in explosive contaminated groundwater using direct push technology.

BENEFIT: The use of in-situ sensors to measure groundwater constituents has significant technical and cost saving benefits over the standard approach of sampling and analyzing groundwater. Measurements taken in-situ leave little opportunity for the parameter values to change, causing many traditional precautions to be unnecessary. A typical sampling program is conducted on a quarterly basis or even monthly in extreme cases. As a result, it is assumed that natural changes in the groundwater occur on a timeframe longer than the sampling frequency. Using sensors, the frequency of the measurement is limited only by the time required for a measurement to stabilize. In addition, the sensor measurement frequency can be easily changed from off-site, enabling the investigator to tailor the measurement cycle to the speed at which the parameter in question is changing. Installation costs are required for an in-situ sensor system and some minor costs are incurred for maintenance; however, once the remote system is operating, the only costs incurred are for data collection from a computer data logging system. Because of the initial capital cost of the sensors, the in-situ system would be more costly than standard sampling for a two to three year period, after which, the lower annual costs of the sensors would result in significant long term cost saving.

ACCOMPLISHMENTS: The detection limits were determined for TNT, Tetryl, DNT, TNB and DNB using a Voltammetric Analyzer in the differential pulse mode with a carbon fiber working electrode. All were determined at 100 ppb with the exception of Tetryl which was determined to be 500 ppb. The measurements exhibited long term stability (hours) using laboratory water spiked with the measured compounds. Also observed was the location of the peak in the voltammogram. All compounds with the exposed -NO2 group appeared to have similar voltamograms as the parent explosive compound and would be expected to be a positive interferent to the measurement. Chromate was found to be interferent free. Four groundwater samples collected from the Umatilla Army Depot were analyzed for explosives. These groundwater samples were also analyzed according to EPA Method 8330 for verification and found to contain varying levels of RDX, TNT, TNB and HMX.

TRANSITION: Transition of this technology is directly related to the potential significant cost-savings associated with the use of in-situ sensors. A significant portion of DoD's restoration budget goes for long-term monitoring costs. Most of the cost is associated with the collection of samples, disposal of purge water, and subsequent sample analysis. This cost will only continue to increase as more sites are added to the cleanup list. In-situ sensors offer an alternative to routine sampling and analysis and can result in significant long term cost savings to military installation in and outside the U.S.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Technology for Wide-Area Screening of ERC-Contaminated Soils; CU-1228

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Colin Cumming; Nomadics, Inc. – Stillwater, OK

FY 2001 FUNDS: $300K

DESCRIPTION: There is a need for technologies that can rapidly screen the millions of acres of Department of Defense (DoD) lands suspected of having soil contaminated with energetic compounds. Nomadics developed an advanced landmine detection capability based on a breakthrough technology. Research has shown that the energetic material originating from a landmine tends to be spatially heterogeneous. In order to ensure detection of a mine by soil sampling, Nomadics demonstrated that sufficient soil must be sampled in a spatially distributed fashion around the mine. The landmine detects ultra-low concentrations of explosives in the headspace above mines and in the soils close to mines. This level of sensitivity comes from the use of an amplifying fluorescent polymer (AFP) sensing technology developed at MIT. The AFP-based detection technology is primarily focused on nitroaromatic compounds. Some of these are contaminants derived from the explosive-related compounds (ERCs), while others are formed through biodegradation and photochemical degradation of the ERCs. The amplifying polymer responds primarily to electron-deficient aromatic compounds. This technology is sensitive to analyte concentrations 5 to 6 orders of magnitude lower than the currently fielded soil analysis technologies. The proposed effort will evaluate the relevance of the soil sampling and detections methods developed for landmine detection to wide area screening, then develop and evaluate a novel standoff approach based on the use of the AFP sensing technology.

BENEFIT: By combining such a high sensitivity detector with an advanced high-speed sampling system, rapid and highly reliable wide-area screening is possible. Nomadics has developed an electrostatic precipitator-based soil sampling system that can uniformly capture small soil particles rapidly. Large areas can be sampled efficiently and confidently. In addition, the transduction amplification capability of the polymer makes other deployment scenarios possible, including the potential to perform true standoff detection. If the method is successful, a great reduction in costs for screening ranges will result. This will be due primarily to the fact that since large areas are screened in a single sample, fewer samples will need to be analyzed to cover a large area. The cost of analysis per sample is much less than for currently accepted laboratory methods, further decreasing costs. Since samples will be analyzed in the field, the turn around time for results will be kept to a minimum. This will enable rapid decisions relating to the level of contamination, and therefore suitability of a range for continued use (or possible need for remediation efforts), to be made on-site.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION: Nomadics will work with collaborators and users to fully explore potentially new and powerful wide-area search paradigms based on ultrasensitivity and speed. The ultimate objective is to place in the hands of users a new approach to wide-area screening. Nomadics has taken several technologies and products from the laboratory into commercial sales and this is the goal for the developed screening technology. As the technology matures and is ready to move forward into production, Nomadics will work with other Defense contractors to ensure that the technology transitions into production. Nomadics has prior experience dealing with licensing, intellectual property management, raising capital, and collaborations.

PROJECT SUMMARY

PROJECT TITLE & ID: Immobilization of Energetics on Live Fire Ranges; CU-1229

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Steffan; Envirogen, Inc. – Lawrenceville, NJ

FY 2001 FUNDS: $300K

DESCRIPTION: The objective is to develop a cost-effective technology to immobilize energetic compounds (RDX, HMX, and TNT) at the soil surface to prevent their migration to groundwater. This technology will be targeted at Department of Defense (DoD) impact ranges that are used for munitions training and testing activities. The goal of this research is to develop an inexpensive soil treatment that can be readily applied over wide and remote areas using helicopters or trucks equipped with spraying equipment. This treatment will be composed of an organic substrate (e.g, molasses, potato starch) to promote biological reduction of the energetic compounds and a solid adsorption agent to bind the parent compounds and reduced energetic products. The variety of inexpensive, readily available substrates and sorbents will be evaluated in microcosm experiments in the laboratory and the most effective combination will be tested in column studies and ultimately in a field trial. Batch adsorption isotherms for each of the explosives will be determined using the following solid sorbents: ground rubber tires, sawdust, rice hulls, oat straw, peat, chitin, seaweed, and kaolinite clay. The sorption isotherms and kinetics with these materials will be evaluated, and the combined role of biotransformation and adsorption in mitigating the transport of energetics to aquifers underlying ranges. The laboratory work will include a combination of small-scale isotherm experiments and microcosm studies for careful analysis of the fate of energetics in the presence of these additives. Laboratory column studies will be performed with selected additives to evaluate their effectiveness for preventing migration of energetics to the subsurface. This research project will carefully consider the cost and availability of additives for large scale applications, and assess methods for delivering the additives over large geographic areas where land-based transportation and delivery is limited.

BENEFIT: There is currently no economically feasible treatment technology to prevent contamination of ground and surface waters at live fire range sites. The large size of these areas and the presence of UXO and vegetation prohibit the use of traditional engineered solutions for preventing migration of energetic compounds from the ranges. Ultimately, the technology developed during this project will result in considerable short-term and long-term cost savings for the DoD by providing: (1) low cost treatment alternatives for existing contamination problems; (2) long-term protection to sensitive ecosystems and groundwater resources at operating facilities; (3) reduced post activity remediation costs; and (4) minimum disturbance of ongoing training operation.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION: Results of the study will be used to evaluate the effectiveness, feasibility, and cost of applying additives over large areas at active range sites to prevent environmental contamination during training operations. The results will also be useful for developing and implementing resource management strategies at training facilities throughout the United States and abroad. Because the study will be performed with the goal of treating active ranges, the technology will ultimately allow protection of environmental resources with minimal interference to existing training activities.

PROJECT SUMMARY

PROJECT TITLE & ID: Topical Lime Treatment for Containment of Source Zone Energetics Contamination; CU-1230

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jeffrey Davis; U.S. Army Corps of Engineers Engineer Research and Development Center – Vicksburg, MS

FY 2001 FUNDS: $275K

DESCRIPTION: This research will investigate the feasibility for in-situ remediation and containment of energetics contaminated soils through the topical application of agricultural grade line. The main objective of this research is to develop a cost effective in-situ process for removing or sequestering energetic compounds in soils. The study will investigate the removal, leachability, sequestration, and toxicity of explosives contamination following treatment. An investigation of lime dosing, and mixing will be performed to evaluate the conditions required to prevent migration of energetic compounds. Current methods for the remediation or containment of source zone energetic contamination involve either ex-situ treatment and/or disposal. These techniques are intrusive and not cost effective. Preliminary results indicate that energetic compounds may be removed with the topical addition of lime. Current experiments show that the addition of an alkaline substance to energetics contaminated soils results in the near complete removal of RDX, TNT, and HMX. These experiments, in water, indicate that TNT undergoes two different removal paths. Approximately 50% of TNT is converted into very large molecular weight molecules. These molecules are extremely insoluble and immobile. The remaining 50% of TNT is converted to relatively small molecular weight molecules. Although these molecules are mobile, the likelihood of biodegradability is greatly enhanced.

BENEFIT: The sustainability of live fire ranges is of paramount importance to ensure continued training at army installations, and technologies are required to eliminate or reduce the possibility of groundwater contamination from explosives compounds. Current research has shown the addition of alkalinity may provide an inexpensive and effective means of reducing the source zone contamination that may possibly lead to ground water contamination. This research will examine both basic and applied aspects of alkalinity but focuses on applied innovative methods to prevent migration of energetic materials from surface soil, by the topical application of lime for energetics destruction and sequestration. This method has been shown to be effective for water and soil contamination.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION: The results of this study will be presented in a series of USACE-ERDC, Waterways Experiment Station (WES) reports, and peer review journals. The information will be presented in a form that will easily be utilized by the user groups including U.S. Army Corps of Engineers (USACE), U.S. Navy, U.S. Environmental Protection Agency (USEPA), and the private sector for demonstration and implementation beyond the proof of concept stage. The reports will include, but not limited to, information such as process mechanisms, treatability protocol, process economics, technical points of contact, and process limitations. Following successful completion of the research effort, a field demonstration may be attempted under the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Fe(0)-Based Bioremediation of RDX-Contaminated Groundwater; CU-1231

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Pedro Alvarez; University of Iowa – Iowa City, IA

FY 2001 FUNDS: $258K

DESCRIPTION: Royal Demolition Explosive (RDX) is one of the most recalcitrant and toxic contaminants in the subsurface. This project seeks to develop a new and efficient method to remediate RDX-contaminated aquifers. This method is based on combining a novel chemical process (reductive treatment with zero valent iron (Fe^0)) with a promising bioremediation approach (*in-situ* reactive zones). This integrated Fe^0-microbial system is more than a mere juxtaposition of two technologies because Fe^0 and some microorganisms interact synergistically to degrade RDX. Aquifer microcosms and flow-through columns will be used to evaluate the feasibility of Fe(0)-based bioremediation and to delineate its applicability and limitations. Microcosms will be used to verify that Fe(0) and municipal anaerobic sludge interact synergistically to enhance the rate and extent of RDX mineralization. Microcosms will also be used to determine the degradation pathway(s) and fate of RDX when degraded by Fe(0), municipal anaerobic sludge, or both. Batch experiments (without aquifer material) will also be conducted with model iron oxides and reference strains of dissimilatory iron-reducing bacteria (DIRB) to investigate the potential for microbial depassivation and formation of reactive surface-bound Fe(II) species. Flow-through columns will be packed with a layer of Fe(0) filings (sandwiched between layers of aquifer material) to simulate permeable reactive Fe(0) barriers. The columns will be fed continuously with RDX-spiked synthetic groundwater, and some columns will be bioaugmented to evaluate the overall effect of microbial processes (e.g., growth, hydrogen consumption, and mineral dissolution and precipitation) on the permeability and efficiency of Fe(0) barriers. These columns will also be used to complement the batch experiments evaluating how iron-reducing bacteria modify the surface chemistry of iron oxides that passivate Fe(0) and to observe microbial colonization of the Fe(0) layer by indigenous microorganisms and added cultures. This latter task will include characterizing how the microbial community structure evolves spatially through the barrier by determining biomass concentration using phospholipid fatty acids analysis (PLFA) and community structure with denaturing gradient gel electrophoresis (DGGE) analysis of 16S rRNA gene polymerase chain reaction products. Selected columns will also be used to determine how potential co-contaminants (TNT and HMX) affect RDX removal efficiency.

BENEFIT: While the development of a cost-effective and sustainable remediation approach has great intrinsic merit, this project also has significant extrinsic merit related to enhancing the understanding of biogeochemical interactions in contaminated aquifers and the role of mineral surfaces in natural attenuation. This project will also provide a stronger basis for designing reactive barriers to intercept important exposure pathways associated with groundwater contamination by a wide variety of redox-sensitive hazardous wastes.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION: The project team will seek to collaborate with other scientists and contractors at Department of Defense (DoD) sites to conduct controlled field demonstrations. Information derived in this project will enhance the understanding of biogeochemical interactions in contaminated aquifers and provide a stronger basis for designing of reactive barriers to intercept important exposure pathways associated with groundwater contamination by a wide variety of hazardous substances. Therefore, the ultimate beneficiary will be the general public through improved risk management and enhanced environmental quality.

PROJECT SUMMARY

PROJECT TITLE & ID: Remediation of Explosives Contaminated Groundwater with Zero-Valent Iron; CU-1232

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Paul Tratnyek; Oregon Graduate Institute of Science & Technology – Beaverton, OR

FY 2001 FUNDS: $291K

DESCRIPTION: Explosives that occur as groundwater pollutants at Department of Defense (DoD) sites are nitroaromatic compounds (TNT, trinitrobenzene, and various di- and mono-nitrotoluenes) or nitramines (RDX, HMX, and Tetryl). Under favorable conditions, most of these compounds are reduced rapidly by zero-valent iron (Fe^0), which suggests that permeable reactive barriers containing zero-valent iron (FePRBs) might be useful for remediation of groundwater contaminated with these explosives. However, all of the early work on explosives reduction by Fe^0 was done as batch experiments, usually with mono-nitro aromatic model compounds, and this system produces dissolved aromatic amines as the major products. During the course of the recently completed SERDP-SEED project, the project team found that columns of Fe^0 removed large quantities of TNT and associated reduction products. The unexpected absence of TNT or its degradation products in the column effluent (in contrast to what the researchers and others have observed in batch experiments) is likely due to greater sequestration on Fe^0 under conditions representative of those encountered in field applications. Analogous processes are expected for RDX and other nitramine explosives. Although these results suggest that application of Fe^0 to the treatment of explosives contaminated groundwater may be far more straight-forward then previously recognized, there are several issues that should be addressed before full-scale demonstrations are attempted. This project will investigate (i) whether any of the products can be released from the Fe^0 back into the groundwater, and (ii) whether complex mixtures of contaminants and/or groundwater constituents will significantly alter long-term performance. Specifically, the project team will investigate the products and kinetics of removal of TNT and RDX using columns in the laboratory and at the Umatilla Chemical Depot. The team will use a variety of methods to extract and characterize all residues of TNT and RDX, determine the effects of changing several key operating conditions, and integrate all of these results in a reactive-transport model that should be sufficient to begin the design of a full-scale demonstration.

BENEFIT: If successful, this project will expand the scope of application of FePRBs (a proven technology for in-situ and passive remediation of several contaminants, including chlorinated solvents and chromate) to groundwater contaminated with a variety of explosives, including TNT and possibly RDX. The project researchers anticipate that if the laboratory and pilot demonstrations are successful, it will be possible to take this technology to full scale in the near term. Two approaches for implementing the Fe^0 system for explosives/energetics in groundwater include an above-ground canister or an in-situ permeable reactive barrier.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION: It is anticipated that the FePRB approach would be applicable at a number of other sites. Based on past experience with installation and performance of FePRBs for chlorinated solvents, the team anticipates that implementation of an FePRB for explosives could be accomplished in conjunction with commercial vendors (e.g., EnviroMetal). This project intends to transition through the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Application of a Flash Pyrolysis-GC/MS Assay for Documenting Natural and Engineered Attenuation of Nitroaromatic Compounds; CU-1233

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Eugene Madsen; Cornell University – Ithaca, NY

FY 2001 FUNDS: $203K

DESCRIPTION: Nitroaromatic compounds pose serious threats to environmental quality. Large groundwater plumes of RDX, HMX, TNT, and DNT are associated with sources on Department of Defense (DoD) live fire ranges, as well as explosives manufacturing and other facilities. Development of chemical "fingerprints" for nitroaromatic compounds would allow their fate in field sites to be quantitatively and qualitatively measured, thereby providing a sound scientific and technological basis for managing site cleanup. This project seeks to build on existing knowledge of the chemical and microbiological processes that influence nitroaromatic compounds in the laboratory and in real-world field sites. The objective is to implement a novel assay that will provide new information about relationships between attenuation and geochemical conditions that may prevail or be established at contaminated DoD sites. The mechanisms of contaminant attenuation expected to operate naturally and in engineered settings for TNT, RDX, and HMX include microbial cometabolism and chemical processes that reduce, polymerize, and bind the contaminant. If the contaminant is DNT, microbial use as a carbon and energy source (hence mineralization) is possible although cometabolic reduction and binding to soil is likely. The reasons for field persistence, hence plume migration for all of the 3 co-metabolized explosives mentioned above is likely one or a combination of the following: toxicity; insufficient organic carbon to drive co-metabolism; insufficient carbon in sediment matrix to bind reduced products; improper redox potential to cause irreversible binding to soil; and nutrient limitations. After developing the means to characterize type and degree of polymerization, this project will be able to devise ways to engineer site conditions to enhance polymerization reactions and explain why and how nitroaromatics have attenuated naturally in some sites and persisted in others. Key assays for discerning the extent of nitroaromatic humification include High-Performance Liquid Chromatography (HPLC) analysis of the reduced monomers (or oligomers), assessing their leachability from site soils, and assessing their degree of incorporation into soil organic matter by pyrolysis Gas Chromatograph/Mass Spectrometer (GC/MS).

BENEFIT: Despite decades of laboratory, enrichment-based biodegradation studies, clear criteria do not yet exist to seek field evidence for attenuation of nitroaromatics or enhancement of the process. This project seeks to develop attenuation criteria (chemical "fingerprints") via a novel suite of chemical, and microbiological measures applied to laboratory experiments and field samples.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION: This project may serve as the foundation for a comprehensive plan for assessment, classification, implementation, and enhancement of the attenuation of nitroaromatics in contaminated DoD sites.

PROJECT SUMMARY

PROJECT TITLE & ID: Sequential Electrolytic Degradation of Energetic Compounds in Groundwater; CU-1234

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Tom Sale; Colorado State University – Fort Collins, CO

FY 2001 FUNDS: $110K

DESCRIPTION: Energetic compounds (e.g. TNT, DNT, RDX, HMX) are widely present in groundwater at DoD facilities. Of primary concern is the incomplete degradation of the energetics resulting in compounds that may pose a greater risk than the original. Reflecting on the scope and nature of the problem, there is a need for new technologies that can cost effectively address potential risks posed by energetic compounds in groundwater. This project involves experiments that will assess the efficacy of flow through electrolytic reactors (e-barriers) to abiotically mineralize dissolved phase energetic compounds in groundwater. The potential of the e-barrier to provide the multiple sequences of reduction and oxidation necessary to completely degrade energetic compounds is perhaps the most distinguishing attribute of this approach. The objective of this project is to develop scientific insights regarding electrolytic oxidation and reduction of energetic compounds, support analysis of the economic feasibility treating energetic compounds via electrolytic processes, and provide a basis for a field demonstration. Ongoing research at Colorado State University (CSU) has demonstrated the potential utility of electrolytic degradation of organic compounds in a permeable reactive barrier format. Flow through e-barriers involves passing contaminated water through charged porous electrodes, resulting in sequential oxidization and reduction of aqueous phase contaminants. Research to date has demonstrated that e-barriers can effectively degrade chlorinated solvents in a laboratory setting. However, research is needed to evaluate the application of an electrolytic approach to degrade cyclic organic compounds such as RDX or TNT. Primary elements of this research include batch voltammetry experiments, flow through column studies, and documentation of results. Voltammetry experiments will involve RDX, TNT, HMX, and DNT. These tests will allow the project team to quickly explore issues of optimal electrode materials and operating voltages. More rigorous analysis of treatment efficacy will be achieved using column flow through electrolytic reactors. Column studies will track degradation of RDX and TNT and the production of intermediate compounds of concern.

BENEFIT: If successful, this research will provide three key benefits. The first benefit is the fundamental scientific insights regarding electrolytic oxidation and reduction of aqueous phase energetic compounds. The second is a basis for evaluating the economic feasibility of treating aqueous phase energetics via electrolytic processes. Finally, a basis for a field demonstration is formed. The project teams aims to determine new scientific knowledge and a new technology that cost effectively addresses risks posed by energetics in groundwater.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION: The research conducted through this project will synergistically complement ongoing e-barrier projects funded by the National Science Foundation, United Technologies Corporation, the Solvents in Ground Water Research Consortium, and the Environmental Security Testing and Certification Program.

PROJECT SUMMARY

PROJECT TITLE & ID: Ecological Risk Assessment of Perchlorate in Avian Species, Rodents, Amphibians, and Fish: An Integrated Laboratory and Field Investigation; CU-1235

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Ronald Kendall; Texas Tech University, The Institute of Environmental and Human Health – Lubbock, TX

FY 2001 FUNDS: $1,740K

DESCRIPTION: The focus of this project is to continue to expand the knowledge base for environmental perchlorate contamination issues with field and laboratory studies designed to assess ecological risks associated with environmental perchlorate contamination. The principle objective of this research will be to examine the impact of environmental exposures of perchlorate on birds, rodents, fish, and amphibians at Longhorn Army Ammunition Plant (LHAAP) near Karnack, TX. Specifically, bioavailability of perchlorate across trophic levels will be evaluated and toxicological impacts of perchlorate on exposed biota will be assessed.

Ecological receptors deemed to be at risk from exposure to perchlorate will be identified through a number of inter-related sub-projects including analytical, terrestrial, and aquatic toxicology as well as ecological modeling. Important routes of exposure and potential food web-related exposure pathways will be determined. Sensitive markers of perchlorate-related toxicity will be used to assess ecological impacts of perchlorate exposure. Long-term risks to exposed populations of birds will be evaluated using individual-based population models driven by inputs specific to perchlorate and the abiotic conditions present at the contaminated site. Movement of perchlorate within abiotic and biotic components of the ecosystem will be assessed with ecological modeling.

BENEFIT: This research program will result in the identification of perchlorate-related ecological risks and in the development of perchlorate-specific models of exposure and toxicity that will be useful for assessment of perchlorate-contaminated sites. Models of exposure and toxicity may also be useful for evaluation of remediation techniques. Remaining ecological concerns related to environmental perchlorate contamination will be addressed.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION: Results of this research project will likely be used to establish regulatory standards and cleanup criteria for perchlorate. Information gained during the conduct of the proposed research will be transitioned to agencies within the DoD, the US EPA, and other federal state agencies and the general scientific community through reports and peer-reviewed publications. The products of this research will provide a framework of risk assessment methods and criteria necessary to define acceptable concentrations of perchlorate within ecological systems. These data will be useful not only in the characterization of LHAAP, but will be applicable for use in the assessment of other perchlorate-contaminated sites operated by DoD, and sites potentially affecting valuable water supplies.

PROJECT SUMMARY

PROJECT TITLE & ID: The Effects of Ammonium Perchlorate on Reproduction and Development of Amphibians; CU-1236

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James N. Dumont; Oklahoma State University– Stillwater, OK

FY 2001 FUNDS: $137K

DESCRIPTION: Perchlorate is prevalent and persistent in the environment and negatively effects biological processes. There is a potential threat to human health and the health of the ecosystems and the organisms that inhabit them. This project will examine the long-term consequences of exposures to perchlorate using the common laboratory amphibian, *Xenopus laevis*, as a surrogate for native species. The objective is to study the longer-range effects of lower, environmentally relevant concentrations than previous studies performed by this project team. The effects of continuous exposure beginning with young embryos through metamorphosis, the effects of naturally contaminated water, the possible mitigation of effects with iodine, the potential effects of consuming plants that have bioaccumulated perchlorate, changes in pigmentation, and the effects of perchlorate on the reproductive capacity of adult females are all areas that will be explored. Adult females will be induced to breed and the quality of egg clutches will be determined. These adults will then be exposed to concentrations of perchlorate for four months, the time required to complete another cycle of vitellogenesis. At the end of the treatment, they will be bred again to the same males and again the quality of egg clutches examined. Parameters that will be noted in studying the variety of amphibians include toxicity, growth, metamorphosis, ability to recover from exposure, histological changes of the thyroid or other organ systems, and thyroxin levels during or following treatments. Treated tadpoles will be exposed to UV irradiation to determine the effects of altered pigmentation on UV sensitivity. Since some plants, which are important food sources for some amphibian tadpoles, bioaccumulate perchlorate, native amphibian species will be reared on perchlorate-laden food (e.g., hydroponically grown lettuce) and their growth and development monitored. Thyroid histology and thyroxin levels and perchlorate body burdens will be monitored in treated embryos and adults. Laboratory tests will be conducted with culture medium and native contaminated water with *Xenopus* and native species to determine if increased iodine levels mitigate the effects of perchlorate on this endocrine system.

BENEFIT: The benefit of this research is to provide a baseline for understanding the environmental effects of perchlorate on amphibian development. It will assist in remediation efforts and will aid in establishing acceptable environmental levels. The data will be useful for evaluating environmental risks from perchlorate-contaminated surface and ground water and will provide guidance to organizations that must use or dispose of ammonium perchlorate stockpiles. The use of a variety of native amphibian species will allow inter-species comparisons of perchlorate sensitivity.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION: The goal of this study is to acquire knowledge that is directly applicable to environmental milieu that is or may become contaminated with ammonium perchlorate. These studies are applicable to private industry and state and federal governmental agencies that manufacture or use ammonium perchlorate or who seek to mitigate the potential effects of this compound on amphibian populations. The investigators on this project are available to consult with any organization, institute, agency or group who wish to discuss the data from these studies.

PROJECT SUMMARY

PROJECT TITLE & ID: Effects of Perchlorate on Developing and Adult Birds; CU-1242

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. F.M. Anne McNabb; Virginia Tech – Blacksburg, VA

FY 2001 FUNDS: $222K

DESCRIPTION: This project is designed to establish safe exposure levels for perchlorate in developing and adult birds and to develop and assessment endpoints for determining the impact of perchlorate exposure in birds. The main focus of the experimental work will be to evaluate perchlorate effects using an array of endpoints that evaluate thyroid function, growth and development. Laboratory dosing studies of two wildlife species of birds Bobwhite quail (*Colinus virginianus*) and Mallard ducks (*Anas platyrhynchos*) will be used. The objectives of the research include establishing safe exposure levels of perchlorate for embryos, chicks, and adults based on the effects of ammonium perchlorate (AP) on thyroid function, growth and development. Another objective is to evaluate measurements of thyroid function that may be used as assessment endpoints for determining the impact of perchlorate exposure in birds. AP will be administered in deionized water onto the air cell of fertile eggs prior to incubation. For studies in chicks and adults, AP will be added to their drinking water. To establish safe exposure levels of perchlorate for the embryos, chicks, and adults, range finding studies will be conducted. The range finding studies will allow the project team to determine the appropriate amount of AP to use in the dose-response studies. The dose response studies of AP exposure will be performed using thyroid effects and indicators of growth and development as endpoints in embryonic, chick and adult life stages of quail and ducks.

BENEFIT: This research will establish safe exposure levels for perchlorate in birds and develop assessment endpoints for determining the impact of perchlorate exposure in birds. Laboratory dosing studies of two wildlife species of birds will be used to establish safe exposure levels at three life stages for avian species. The main focus of the experimental work will be to evaluate perchlorate effects on thyroid function and on growth and development during embryonic, early posthatching and adult life.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION: This research will provide comprehensive information, based on an array of endpoints, about the effects of perchlorate on avian thyroid function, growth and development at three life stages (embryos, chicks and adults) of two avian wildlife species. This information will be of direct use to the Environmental Protection Agency (EPA) in developing standards that will protect a key wildlife group as part of the goal to "establish standards that are protective not only for humans but for the environment as a whole." This work will also evaluate practical assessment endpoints that can be used in field studies to assess environmental perchlorate exposures. A comprehensive understanding of perchlorate effects in birds will be gained through an array of endpoints measured in the laboratory.

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Understanding of Fenton-Like Reactions for In-Situ Remediation of Contaminated Groundwater Including Treatment of Sorbed Contaminants & Destruction of DNAPLs; CU-1288

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard J. Watts; Washington State University – Pullman, WA

FY 2002 FUNDS: $169K

DESCRIPTION: In-situ chemical oxidation (ISCO) using modified Fenton's reagent (hydrogen peroxide and catalysts) holds the potential to rapidly treat many of the Department of Defense (DoD) sites that are contaminated with halogenated organic chemicals. Research suggests that modified Fenton's reagent used for ISCO is capable of the rapid destruction of biorefractory contaminants, enhanced desorption of sorbed contaminants, and enhanced destruction of dense non-aqueous phase liquids (DNAPLs). The proposed research aims to obtain a better fundamental understanding of modified Fenton's reagent as an ISCO process. Two fundamental principles serve as themes for the proposed project. The first is that hydroxyl radicals, while necessary for the oxidation of soluble contaminants, are only partially responsible for the success of Fenton-like ISCO. The second is that naturally-occurring trace minerals may play an important role in Fenton-like ISCO relative to soluble iron catalyst addition. The research will focus on detecting the generation of three transient oxygen species in modified Fenton's reactions: hydroxyl radical, superoxide anion, and the hydroperoxide anion, through trace mineral and soluble iron-catalyzed Fenton's reactions. The importance of each oxygen species will be evaluated for DNAPL destruction and the treatment of sorbed contaminants. Finally, practical delivery and stoichiometry considerations will be evaluated. The proposed research will provide definitive elucidation of mechanisms and integrate the results to provide more effective process design for the full-scale application of Fenton-like ISCO.

BENEFIT: The results of this research will provide a solid foundation for implementing more technically effective and more cost effective Fenton's ISCO process condition to clean up contaminated sites.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The results of this study will be transitioned to conduct controlled large scale pilot studies and controlled field studies where the delivery of hydrogen peroxide, the formation of transient oxygen species, NAPL destruction, and contaminant oxidation and reduction can be throughly monitored with mass balances on all of the contaminant carbon in the system. Such larger-scale transition research could be sponsered through ESTCP or similar programs to investigate the Fenton's process at meso- and/or full scale. If in-situ Fenton's systems can be fully optimized, hydrogen peroxide requirements (the most expensive chemical in the Fenton's process) could be dramatically reduced, providing significantly lower costs for implementation.

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Understanding of In-Situ Chemical Oxidation (ISCO); CU-1289

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Eric Hood; GeoSyntec Consultants – Guelph, Ontario, Canada

FY 2002 FUNDS: $313K

DESCRIPTION: The use of ISCO treatment of chlorinated solvent source areas is rapidly increasing as DoD and other stakeholders search for remedial approaches that reduce long-term operations and maintenance requirements. While ISCO is a promising technology for some chemicals, there remains significant data needs related to reaction kinetics for common Department of Defense (DoD) chemicals, the effects of natural oxidant demand on oxidant mobility and delivery under varying site conditions, and the effects of ISCO on long-term groundwater quality. This project will focus on developing a comprehensive approach to quantifying degradation kinetics during ISCO by permanganate and Fenton's applying this approach to a broad spectrum of common groundwater kinetics. Another aim of this project is developing a rigorous bench-scale experimental methodology to measure the rate and extent of the aquifer matrix natural oxidant demand (NOD) with permanganate and Fenton's reagent and developing a comprehensive conceptual model describing the role of NOD on oxidant mobility in the subsurface. The long-term impacts of ISCO will be researched by identifying significant secondary impacts of oxidant application on groundwater geochemistry and microbial activity at the field scale. Finally, the project team will develop a ISCO guidance document for chlorinated solvent remediation, in association with the other ISCO project teams selected under this Statement of Need (SON). The document will includes specific guidance on technology applicability, protocols for effectively employing site-specific laboratory and pilot-scale treatability testing, design guidance for oxidant delivery systems, and approaches for effective technology performance monitoring and validation.

BENEFIT: This research is designed to significantly improve the current understanding of reaction mechanisms and kinetics for chemicals commonly found at DoD facilities and the behavior of permanganate and Fenton's reagent in the various geological and geochemical environments encountered at DoD sites. This fundamental knowledge, which will be distilled into a guidance document, will enable DoD site managers to properly handle the situation and the decision making when dealing with chlorinated solvents.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: GeoSyntec and its co-development partners will transition the performance and applicability data for the ISCO technology to the federal and non-federal sectors through the publication of research articles, the distribution of videos and pamphlets, the presentation of test results at conferences, and the development of a project web page. These efforts should help transition this technology within the DoD and the DOE. GeoSyntec will also market the technology to non-federal defense contractor facilities, to make them aware of the potential to use the technology to reduce environmental liabilities.

PROJECT SUMMARY

PROJECT TITLE & ID: Reaction and Transport Processes Controlling In-Situ Chemical Oxidation of DNAPLs; CU-1290

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Siegrist; Colorado School of Mines – Golden, CO

FY 2002 FUNDS: $154K

DESCRIPTION: Chemical oxidation has emerged as a promising treatment method for remediation of sites contaminated by chlorinated solvents and petrochemicals. Fundamental and applied laboratory research has elucidated many aspects of the reaction stoichiometry, degradation pathways, and kinetics for common organic chemicals in aqueous systems as well as the effects of temperature, pH, and matrix composition. Currently, there are serious gaps in the knowledge base regarding in-situ chemical oxidation (ISCO) for dense nonaqueous phase liquids (DNAPLs). As a result, ISCO applications at DNAPL sites have been limited and those that have occurred have been plagued with uncertain or poor performance. In this project, proven methodologies involving apparatus of varying scales and complexities will be used to explore two common oxidants (peroxide and permanganate) and contrasting oxidant application methods (low to high dose concentrations and low to high delivery densities) to treat different DNAPL masses and distributions under conditions representative of a range of subsurface settings. The research will also address the potential adverse secondary effects of applications of ISCO, as well as the appropriate coupling of ISCO with pre- and post-ISCO treatment operations. There are six technical objectives in this project. The first objective is to determine the interphase mass transfer rates and degradation of DNAPLs using either peroxide or permanganate as a function of oxidant concentration, interfacial cross-flow velocity, and systems properties. Another objective is to determine the effects of porous media of varying properties and subsurface heterogeneity on the DNAPL degradation that can be achieved by ISCO. The third objective is to determine the effects of DNAPL type and distribution on the overall mass reduction achieved and effects on mobile contaminants after varying levels of ISCO treatment. The fourth is to determine how to incorporate ISCO into a coupled treatment approach with either a pre-ISCO treatment step involving mass recovery and/or a post-ISCO step involving natural attenuation. Another objective is to determine if partitioning tracer test methods can be used for characterization and performance assessment at ISCO treated sites. The final objective is to develop a design flow chart and nomographs for ISCO that provide guidance for screening level decision making, characterization needs and treatability studies, and critical design factors and values that support cost-effective implementation of ISCO for a given site and performance goals.

BENEFIT: Completion of this project will yield a knowledge base for the future development of guidance on the principles and practices of ISCO so that it can be selected as a preferred remedy when appropriate and be implemented to reliably achieve a given performance objective.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: Results of this work will produce decision aids that will be designed for future guidance regarding when and how to apply ISCO to cost-effectively remediate DNAPL at a given site, using ISCO either as a stand-alone method or by coupling it with a pre- or post-ISCO operation.

PROJECT SUMMARY

PROJECT TITLE & ID: Optimization of In-Situ Oxidation via the Elucidation of Key Mechanistic Processes Impacting Technology Maturation and Development of Effective Application Protocol; CU-1291

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Beth Fleming; U.S. Army Corps of Engineers Engineer Research and Development Center – Vicksburg, MS

FY 2002 FUNDS: $257K

DESCRIPTION: This project focuses on the idea that soil constituents known to be reactive with chemical oxidizers can dramatically change the biogeochemistry of soils. There are potential benefits of process integration that are dramatic in terms of both cost and performance. The application of chemical oxidizers within non-aqueous phase liquids (NAPLs) is a poorly developed area and there is little data available for use in developing near-field remediation models (primarily with reaction and sorptive mechanisms). The design options are poorly documented and their relative performance has not been evaluated. There are also key safety issues that have not been properly addressed with regard to using chemical oxidizers within ISCO systems. The primary objective of this project is to provide basic scientific information on the impact of applying chemical oxidizers and their fate within soil matrices. There are several secondary objectives of this project. The first is to better understand and define what soil constituents impact transport of primary oxidizers and then determine how chemical oxidizers impact soil systems. Another objective is to provide a better understanding of oxidizer-pure NAPL interactions. The third is to develop and/or refine appropriate reactive, sorptive kinetic models (non-transport). The fourth is to evaluate results using actual soils containing TCE, TNT, and Phenols (two of each). The final objective is to provide a well-documented evaluation of current and developing design protocols, inclusive of key safety issues.

BENEFIT: There are several benefits of this project. The resulting information will be used for refining current design protocols. The definition of the performing mechanisms should lead to significant process optimization. The delineation of those soil constituents that have the greatest impact on oxidizer stability within soil matrices will be achieved. The project aims to evaluate the potential impacts of oxidation processes on receiving soil systems providing insight into post-treatment options. The project team will generate a data base that can be used for later development of biotic/abiotic treatment techniques. The project will develop key kinetic information (reaction and adsorption) and generate process design guidance

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The transition for this project involves the development of a design manual. The project team will submit numerous peer-reviewed papers and provide numerous technical presentations on the following topics: oxidizer fate, soil condition post-ISCO application, NAPL remediation, modeling, design issues. This project intends to transition through the Environmental Security Technology Certification Program (ESTCP). There is a plan to organize an Engineering Foundation Conference on Application of Chemical Oxidation for Soils Remediation working with other teams and SERDP Office on this conference. The research team also provides Corps of Engineers with In-House Expertise on ISCO, enabling further transfer of this project's results.

PROJECT SUMMARY

PROJECT TITLE & ID: Decision Support System to Evaluate Effectiveness and Cost of Source Zone Treatment; CU-1292

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Charles Newell; Groundwater Services, Inc. – Houston, TX

FY 2002 FUNDS: $246K

DESCRIPTION: The DNAPL site paradigm developed in the 1990s has resulted in two competing site remediation approaches: (1) aggressive treatment and removal of DNAPLs and (2) long-term, low intensity containment with management of the DNAPL dissolution products. The objective of this research is to develop easy-to-use tools that will help the groundwater community decide which approach is appropriate at a given site. The project will result in the development of an easy-to-use decision support system that will allow users to: (1) simulate the characteristics of a source zone, (2) simulate the effects of various remediation alternatives, and (3) estimate the resulting remediation costs/benefits and plume patterns over time. The goals of this project include developing a new source evaluation methodology, based on a concept of generic "source settings" that will represent different types of DNAPL source; generating a family of source concentration vs. time curves for each generic source-setting and for key site-specific input data; developing a Source Remediation Cost and Performance Database; applying this methodology to a 20-30 site source zone database; generating a list of general rules regarding when and where various forms of intensive or partial site remediation are appropriate and cost-effective based on case study results and input from the expert panel; and developing an easy-to-use Decision Support System.

BENEFIT: The results of this project will be used by the groundwater community to: (1) apply the general rules derived from the detailed analysis of 20-30 sites to conduct a planning-level "Tier 1" evaluation of intensive source remediation strategies, (2) perform a more detailed "Tier 2" evaluation of the site by entering data into the Decision Support System, representing the source zone as a series of generic source-settings, using the software to visualize the change in the plume over time, and evaluation the costs vs. benefits of source remediation, and (3) reference new research data in the form of a Source Zone Database, a Source Remediation Cost and Performance Database, and results from the source-setting analysis.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: To transfer the knowledge, the project team will rely on two key products: (1) general rules derived from the project's detailed analysis of 20-30 sites, and (2) a Decision Support System, allows users to represent the source zone as a series of generic source-settings. The resulting costing and predictive features in the software will generate cost data and help users visualize the plume over time for various source treatment alternatives. The generals rules, generated from project results and input from the expert panel, will be presented in the form of a simple table or graphic, and a short tech-transfer bulletin will be developed for distribution via the internet. The project team also plans to transition the information through peer-reviewed journal articles, HTML files for use as web page, downloadable Source Zone Database and results of the application of the methodology to these sites, downloadable Source Remediation Cost and Performance Database, downloadable Decision Support Software and User's Manual, presentations at conferences, and information bulletins on commonly-used online groundwater groups and on technology-transfer systems such as EPA's CLU-IN program, and the Remediation Technologies Development Forum.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of Assessment Tools for Evaluation of the Benefits of DNAPL Source Zone Treatment; CU-1293

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Linda Abriola; University of Michigan – Ann Arbor, MI

FY 2002 FUNDS: $299K

DESCRIPTION: Despite its importance to the evaluation of alternative site remediation and management options, relatively little research has been conducted to assess the post-treatment distribution, mass transfer, and biotransformation of dense non-aqueous phase liquids (DNAPLs) following in-situ treatments. This project is a multidisciplinary integration of laboratory, field, and modeling studies designed to provide a more comprehensive understanding of these issues and to develop tools and protocols for field monitoring and cost/benefit analyses. Various levels of treatment and remediation technologies/approaches will be investigated under heterogeneous subsurface conditions representative of known contamination sites. Application of the developed tools will be evaluated at selected DNAPL field sites. The research plan is organized around five tasks: (1) Bench-scale assessment of DNAPL recovery and contaminant fluxes following source zone treatment; (2) Evaluation of the potential for microbial reductive dechlorination in treated source zones; (3) Refinement, validation, and application of a numerical model for source zone flux prediction; (4) Field mass flux estimation protocol development and evaluation; and (5) Cost-benefit analysis tools development.

BENEFIT: The results of the research will provide Department of Defense (DoD) site managers with tools and protocols designed to assess the effectiveness and cost-benefit potential of DNAPL source zone treatments. Anticipated project deliverables include: (a) field sampling and monitoring protocols to quantify pre- and post-treatment mass fluxes; (b) biological probe technologies to assess chlororespiring activity in source zones, and (c) cost analysis tools designed provide simplified and detailed cost estimates for competing technologies. These assessment tools are intended primarily for implementation within a pre-treatment decision process, in which several source zone treatment technologies would be evaluated in terms of both cost and potential for mass flux reduction.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The primary receivers of the project deliverables are site managers involved in source zone remediation and regulatory officers responsible for overseeing and approving such remedial actions. To reach these audiences, a series of transition programs targeted toward source zone treatment will be developed in cooperation with the State of Michigan Department of Environmental Quality (DEQ) and the U.S. Environmental Protection Agency (EPA). The Michigan DEQ has agreed to provide in-kind support, if possible, to promote source zone monitoring and assessment at additional field sites. The project team has discussed potential collaboration and financial support from the U.S. EPA to develop white paper(s) describing the implementation of source zone assessment protocols and the sponsorship of a source zone assessment workshop(s) involving regulatory officials at the state and national level, government agencies, and relevant industries. Additional avenues that will be explored for technology transfer include the Interstate Technology and Regulatory Cooperation Work Group, US. EPA Groundwater Remediation Technologies Analysis Center, and the U.S. EPA Hazardous Waste Clean-up Information Site.

PROJECT SUMMARY

PROJECT TITLE & ID: Mass Transfer from Entrapped DNAPL Sources Undergoing Remediation: Characterization Methods and Prediction Tools; CU-1294

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Tissa Illangasekare; Colorado School of Mines – Golden, CO

FY 2002 FUNDS: $220K

DESCRIPTION: Non-aqueous phase liquids (NAPLs) exhibit complex flow and entrapment behavior in naturally heterogeneous subsurface systems. Any type of risk analysis to determine the effectiveness of remediation has to be conducted using the spatial and temporal distribution of NAPL concentrations in the contaminant plume. The physical process that is fundamental to determine both the pre- and post-remediation status of the contaminant plume is the mass transfer that occurs from the entrapped NAPL sources. The focus of this project is to understand, quantify, and model the process of mass transfer from source zones where DNAPL is distributed in complex configurations due to unstable behavior and natural geologic heterogeneity. A research study that involves batch and bench-scale experimentation, physical modeling in intermediate-scale laboratory soil tanks, and a validation of predictive modeling tools will be conducted. The research will aim to determine whether the existing site characterization techniques have the capability and refinement to determine the pre- and post- remediation distribution of NAPL mass within the entrapment zones (residual and pools) and whether the current understanding of mass transfer and mixing that occur within DNAPL source zone in heterogeneous subsurface formations are adequate to make predictions on how the dissolved contaminant plume behaves as a result of remediation.

BENEFIT: The knowledge gained and the tools developed will help in the management of waste sites based on the approach of risk based corrective action. The project team will attempt to understand the fundamental processes that control the behavior of plume concentrations so that modeling tools can be developed. The researchers also will aim to characterize and understand the processes that govern mass transfer from complexly distributed DNAPL after application of three common source zone removal/destruction technologies. The impacts of source zone treatment technologies for long-term achievement of end-point DNAPL saturations that results in acceptable downstream contaminant levels.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The project team is currently directing a research project funded by the Army Research Office. This research will help improve the U.S. Army Groundwater Modeling System (GMS). The project team closely collaborates with WaterWays Experiment Station in this research. The modeling tool developed in this work has the potential to be included in GMS.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of a Surface Enhanced Raman Spectroscopy (SERS)-Based Sensor for the Long Term Monitoring of Toxic Anions; CU-1296 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Pamela Boss; SPAWAR Systems Center – San Diego, CA

FY 2002 FUNDS: $100K

DESCRIPTION: Long-term monitoring can be for process control, for performance measurement, or for compliance purposes and can last up to 30 years. Currently, monitoring is done by traditional methods of collecting aqueous samples from monitoring wells or by drilling and collecting soil samples. These samples are taken and then sent to a laboratory for analysis. The collection and laboratory analysis of samples is both time consuming and costly. There is a need to develop new, long-term monitoring technologies that will measure contaminants of concern in-situ/on-site and will minimize sampling time and costs. This project will develop an in-situ sensor that uses cationic-coated, surface-enhanced Raman scattering (SERS) substrates to detect perchlorate, chromate, dichromate, and cyanide anions. The coating attracts the anions to the SERS substrate where they are identified and quantified by their characteristic Raman emission. The cationic coating stabilizes the SERS substrate, thereby extending its lifetime and has a characteristic SERS spectrum, which can be used as an internal calibration. The anions the project team is interested in detecting are polyatomic and exhibit Raman active vibrational modes. Consequently, each one of these toxic anions will exhibit a characteristic Raman emission which can be used for identification purposes. Besides specificity, simultaneous multicomponent analysis is possible due to the high resolution of Raman spectra. Raman spectra can be obtained remotely over optical fibers in real time and there has been significant advances in the development of inexpensive Raman spectrometers, charge-coupled devices, and diode lasers. However, despite these advances normal Raman spectroscopy is, inherently, an insensitive technique. In order to achieve ppb detection limits, the Raman signal needs to be enhanced.

BENEFIT: The development of this long-term monitoring technology has several benefits. The sensors can be used in-situ/on-site. Often the analytical results from traditional methods of collecting aqueous samples are questionable due to sampling handling procedures and biochemical interactions. This sensor should reduce sampling time and cost.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: Besides the detection of anions, this technology has the capability to detect volatile organic compounds (VOCs), metal ions, drugs, explosives, and agents used in chemical warfare. The technology fits into a number of areas of interest including bioremediation, compliance, and monitoring. Consequently, it is believed that once the technology has achieved proof-of-concept, it will lead to more extensive follow-on development efforts within SERDP and future transition to DoD, other SERDP partners, and the private sector as a cost effective monitoring capability for the Environmental Restoration Program.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrated Automated Analyzer for Monitoring of Explosives in Groundwater; CU-1297 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Yuehe Lin; Pacific Northwest National Laboratory – Richland, WA

FY 2002 FUNDS: $100K

DESCRIPTION: The closure and remediation of former ammunition plants and military facilities requires accurate characterization of soil and groundwater contamination. It has been found that the distribution of contamination is often highly heterogeneous, requiring numerous samples and analyses for these sites to be adequately characterized. The objective of this research is to develop a portable analytical system based on the on-line/on-chip coupling of a miniaturized, meso-scale sequential injection for fast and automated sample processing with a microfabricated capillary electrophoresis/electrochemical detector for fast separation/detection of explosives and their degradation products in groundwater contamination at Department of Defense (DoD) sites that are undergoing closure and remediation. The full realization of the development of a portable analytical system is greatly dependent upon exploring and resolving specific technical issues. The main problems involved in the determination of explosives and their degradation products are the low concentration levels of analytes and the complexity of environmental sample matrixes, which makes sample preconcentration and purificaiton necessary prior to subsequent analysis. In this project, automated solid-phase extraction (SPE) and solid-phase microextration (SPME) techniques will be used for sample preconcentration prior to capillary electrophoresis (CE)/electrochemical detection steps. The project will focus on the development of fast separation protocols and a CE/electrochemical detector on chip. The researchers will also focus on on-line/on-chip coupling of sequential injection (SI) pretreatment system with microfabricated CE/ECD. Finally, the project team will evaluate the integrated analyzer for analysis of groudwater samples.

BENEFIT: The portable analyzer will allow fully automated sample pretreatment, and fast separation and detection of multi-components of explosives and their degradation products. Primary cost-saving benefits are based on minimizing routine sampling and analysis of groundwater samples, which will result in significantly lower cost associated with sampling, disposal of purgewater, and analysis of samples collected.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The field-portable analyzer developed in this project will be broadly applicable to many hazardous waste sites owned by DoD and DOE. Although the target analytes in this project are explosives, the analyzer can also be extended to other pollutants. The analyzer will be highly integrated, automated, and compact. It will be used for on-site/real-time analysis, eliminating the cost of sample packaging and shipping and reducing the waste produced. Since the technique combines the automated sample pretreatment and fast separation and detection, it will greatly increase the sample throughput and reduced labor costs. The total cost for long-term monitoring using this technique is estimated to be reduced by a factor of about 100-fold. One factor for transition is the availability of interested sites. Collaborators at the Engineer Research and Development Center (ERDC) have been working on monitoring and remediation of explosives contaminated site for many years. They have strong capabilities in method and development for analyzing explosives and have successfully conducted 4 field demonstrations of a thermal desorption sampler for volatile organic compounds. They will be responsible for field-testing of the prototype analyzer, if the project goes further into a continued development effort.

PROJECT SUMMARY

PROJECT TITLE & ID: Long-Term Monitoring for Explosives-Contaminated Groundwater; CU-1298 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Fisher; Nomadics, Inc. – Stillwater, OK

FY 2002 FUNDS: $100K

DESCRIPTION: The research team, specializing in creating sensors for mobile and field applications, will apply proven technologies to develop a sensor for monitoring explosives in groundwater. The core technology for this sensor is a polymer-based platform developed by the Massachusetts Institute of Technology (MIT) and Nomadics that has demonstrated the ability to detect TNT and related explosive compounds with far greater sensitivity than any other technology currently available. In fact, the Nomadics technology is 50 times more sensitive than ion mobility spectrometry (IMS) and 1,000 times more sensitive than micro-electron capture detection (µECD). This technology has been implemented in a system for detecting landmines and has proven to be quite effective. As a platform technology, this sensor can be integrated into a number of system configurations, including downhole probes, cone penetrometers, *in-situ* monitors for remediation process streams, and other accepted methodologies for site monitoring. In this effort, the team will perform a proof of concept demonstration using a downhole probe model. Nomadics will build a prototype downhole probe and demonstrate its ability to detect trace amounts of TNT and related explosives. Based on experience in the field by Nomadics and the published results of others, it is clear that the soil in proximity to buried landmines contains energetic material. The material partitions between the soil, water, and air in ways that have been well documented. Some of this material is transported into groundwater, where it is detectable by the Nomadics polymer. The Nomadics AFP-based detection technology research has primarily focused on nitroaromatic compounds. Some of these are associated with the explosive material itself, while others are associated with biodegradation and photochemical degradation of the explosives-related compounds (ERCs). The amplifying polymer responds well to electron-deficient components. Therefore, the ERCs that are most likely to be detected are those containing nitro groups on an aromatic ring such as 1,3-DNB, TNT, 2,4,6-TNB, 2,4-DNT, 2,6-DNT, 4-amino-2,6-DNT, 2-amino-4,6-DNT, and tetryl.

BENEFIT: This approach offers virtually real-time sensing of explosives with essentially no waste production at a greatly reduced life cycle cost over what is currently available. Because the sensor technology resides on a modular platform, this concept can be applied to a number of other analytes by replacing the sensor mechanism. It may even be possible to develop probes capable of monitoring multiple analytes.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: Taking a technology from the lab to commercialization is a complex process and demands far more than technology development skills. In particular, skills in licensing and intellectual property management are required, as is experience in strategic partnering and collaboration. Nomadics anticipates that the proposed system could be fielded for less than $3000 per probe. Considering that reports for the Department of Energy estimate water sample costs at $300-425 per sample, ten samples would recover the cost of a probe. The fully automated system with programmable winch, wireless connectivity, solar power, and other options would, of course, cost more. However, many of these costs would be offset in a scenario of long-term sampling, particularly with the savings realized through reduced dispatches of personnel. Because of the modular design, the TNT sensor can be replaced with platforms that measure different parameters so that the system would be useful for other environmental monitoring applications.

APPENDIX B
Compliance Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Investigations of Improvements in Environmental Accountability, Safety, Process and Training for New Technologies and Deconstruction Methodologies; CP-819

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Raymond Lovett; National Environmental Education & Training Center – Indiana, PA

FY 2001 FUNDS: $2,476K
FY 2002 FUNDS: $2,500K

DESCRIPTION: New environmental technologies are often designed for efficacy with little consideration given to the safety of the technology to an operator, a maintenance worker or the community. As a result, significant time and energy is spent on re-engineering technologies to address health and safety issues. This project sought to assist development of maximal worker and environmentally protective processes and technologies. The goal was to produce efficient processes and technologies that are intrinsically safe and environmentally protective. The new processes and technologies were accompanied by upgraded information and training packages that foster safe, efficient implementation.

The project focused on two specific areas, improvement of health and safety in new environmental technologies and development of more efficient processes in the recycling of ships. Health and safety aspects included development of internet-based software that allow technology developers to incorporate safety in their designs and a series of field safety evaluations of environmental technology tests that result in the production of safety documents and an informational compact disk. The ship recycling project involved the cooperation of the Navy and private companies and investigated processes with a view towards improving them. Improvements involved process changes or technology introductions. Studies concerned actual cutting, recycling issues, improvements to planning, and development of more efficient training.

BENEFIT: The tools and data developed under this project, when coupled with existing "engineering design and management tools" will assist designers and technology implementors in evaluating and assessing health and safety issues in a focused, systematic way. It will lead to a consideration of worker and environmental safety and health implications associated with field (or production) use of innovative technology, and minimize the occurrence of health and safety concerns before and during end-user implementation.

ACCOMPLISHMENTS: Integrating the project database of the existing TEXPERT with a new object oriented inference engine, a new design and version of TEXPERT was developed. Decommissioning and decontamination technologies were incorporated into the model as well. The costs associated with ship dismantling and recycling were incorporated into a parametric cost model for budget formulations. Concurrently, flowcharts were developed to help ship dismantlers respond appropriately to the myriad of confusing regulations relating to health and safety regulations, and safety and health issues during the processes of ship dismantling and recycling. The model provides alternative steps in the process that may be less expensive, safer, cleaner, or more productive. Independent verification and validation procedures were developed and applied to the TEXPERT software as well.

TRANSITION: Transition consists of full implementation of an expert system made available on the Internet or on diskette, demonstration at two technology development sites, and integration with a similar DOE program. Implementation of an outreach program via the Internet is also planned.

PROJECT SUMMARY

PROJECT TITLE & ID: Optimization of an Innovative Biofiltration System as a VOC Control Technology for Aircraft Painting Facilities; CP-1104

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kerry Kinney; University of Texas – Austin, TX

FY 2002 FUNDS: $57K

DESCRIPTION: Currently available VOC emission control technologies are costly at the high volumetric flow rates and low contaminant concentrations associated with the ventilation of aircraft hangars. This project will develop an innovative, high flow-rate biofiltration method for treating VOC-laden air emissions. Biofiltration of painting off-gas streams currently is limited, not because of insurmountable technical problems but simply because current systems have not been designed to handle the operating conditions typical at these facilities. Innovative design features and biofilter configurations are being investigated, tested, and applied to an actual Air Force paint spray booth.

The following innovative design features are being investigated for their ability to improve biofilter performance for paint spray booth applications: (1) a recirculating inoculation method to shorten the bioreactor start-up period; (2) directionally-switching operation to improve biomass distribution and prevent clogging; (3) slip-stream feed to maintain high biomass activities during paint spray booth shutdown periods; and (4) an aerosol nutrient delivery system to efficiently deliver nutrients and moisture to the biofilm. Since bioreactor performance is strongly influenced by the contaminants being treated, the effectiveness of each design modification will be determined under single (e.g., ethyl acetate) as well as multiple [e.g., methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), toluene] contaminant conditions representative of paint spray emissions.

BENEFIT: The project will provide a stable biofiltration system for paint spray booth applications that operate intermittently and emit varying quantities of VOCs. Typical biofilter problems such as long acclimation times, slow response to load changes, and biomass clogging will be overcome. The innovative biofiltration process developed by this project will, therefore, be suitable for venting of aircraft hangars during application or removal of coatings. It has the added advantages of operating at ambient temperatures and minimizing the generation of secondary wastes.

ACCOMPLISHMENTS: The analytical methods, including gas chromatography/ free induction decay for gas-phase volatile organic compounds, have been developed and tested. The research team also has developed and applied a new iodonitrotetrazolium chloride redox method for assessing biomass activity in the biofilter. Results from these tests indicate that the bioreactor acclimation period is very sensitive to the amount of nitrogen initially available in the system and the initial VOC contaminant feed supply. The development of microbial cultures (fungal and bacterial) capable of degrading the major contaminants found in paint spray emissions has been successful. Specifically, microbial cultures that degrade toluene, ethyl acetate, and MEK have been isolated and developed.

TRANSITION: The primary users of the biofiltration technology will be DoD paint spray booth facilities; however, the technology also will be widely applicable to the private sector. Research results are being published in forums that reach a large audience of professionals in air pollution control including the Annual Meeting of Air and Waste Management Association. A web site also will be dedicated to the proposed research and will include brief statements related to research objectives and interim results.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Particulate Emission: Size Characterization and Chemical Speciation; CP-1106

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Adel Sarofim; University of Utah – Salt Lake City, UT

FY 2002 FUNDS: $500K

DESCRIPTION: The objectives of this project are to develop advanced methods for the measurement of the size distribution and composition of particulate matter (PM) emitted from mobile and stationary sources and provide the DoD with the tools needed to characterize and control the emissions from DoD facilities. The data obtained during the evaluation of the instruments will provide a measure of the relative importance of different DoD sources and will be useful for guiding strategies for controlling the emissions from DoD facilities. The cost effectiveness of different measurement methods will be assessed and recommendations made for the best protocols for measurement of fine particle emissions. Two innovative techniques for rapid measurement of fine particles will be used in combination with a dilution sampler. The first is an aerosol time of flight mass spectrometer (ATOFMS) that measures the size and composition of individual articles. The second is a photoelectric aerosol sampler (PAS) which, in combination with a photoacoustic elemental detector (PED) for carbon, provides rapid measurement of the polycyclic aromatic hydrocarbon (PAH)-laden carbonaceous particles which dominate the emissions from combustion sources. These devices will be applied in parallel with more conventional measurement techniques to establish their validity for characterizing the particle emissions from DoD sources. Multiorifice impactors (MOI) combined with chemical analysis will be used to obtain chemical characterization sufficiently detailed to close material balances on the emissions. Optical particle counters (OPC) and differential mobility analyzers (DMA) will be used to obtain detailed size distributions in order to calibrate the ATOFMS and PAS.

BENEFIT: The project will provide DoD with rapid measurement procedures for organic and inorganic particulate emissions at greatly reduced cost per analysis, as well as detailed chemical compositions of major particulate source categories by size. Assessments will be provided of the relative cost of alternative measurement strategies, ease of use, potential use for feedback control, reliability, and speed.

ACCOMPLISHMENTS: Experimental results indicate that PAH partitioning is highly dependent on engine load. PAH emissions from diesel fueled vehicles have higher molecular weights than gasoline engines. JP8 fueled vehicles showed PAH distribution covering the range encountered in both diesel and gasoline fueled vehicles. A good understanding of the impact of dilution and dispersion on the particle size distribution is now available and these processes can be adequately modeled, with the exception of nucleation when it occurs. Photoelectric aerosol sampler (PAS) results show poor correlations with PAH concentrations. Mounting evidence shows that the PAS correlates better with elemental carbon than particle-bound PAHs. This may be due to PAS ionizing only the first layer of the particle-bound PAH. The ATOFMS detected high concentration of magnesium at Hill Air Force Base after a snow fall linking it to a magnesium processor in the Salt Lake area.

TRANSITION: At the end of the source test program, the techniques used in the advanced source test system will be evaluated in terms of ease of use, time of sampling to obtain data, time to analyze data, and capital and operating costs. Negotiations are in progress to produce a commercial version of the ATOFMS. The current project will have developed the calibrations necessary for producing quantitative emission measurements on DoD sources as well as provided a measure of the cost effectiveness of using this technology. Personnel from Hill Air Force Base and the Air Force Research Laboratory will evaluate the ease of transfer of the instruments to the field.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of a Catalyzed Ceramic Filter for Combined $PM_{2.5}$ Removal and VOC and CO Oxidation; CP-1120

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Goldsmith; CeraMem Corporation – Waltham, MA

FY 2001 COMPLETE PROJECT

DESCRIPTION: The objective of this project was to develop high performance filters applicable to the treatment of a number of Department of Defense (DoD) combustion gas streams. The filters are highly compact, ceramic-membrane-coated, silicon carbide (SiC) monolith filters, which could be additionally coated with non-selective catalysts to achieve simultaneous removal of particulate matter while oxidizing vapor-phase volatile organic compounds (VOC) and carbon monoxide (CO). The oxidation catalysts could also result in “passive” regeneration of soot to allow extended continuous operation.

The project was carried out in three phases to develop high performance filters to control pollutant emissions from combustion gas sources: (1) Development and characterization of SiC monolith filters which would be operated in various modes, either for high-efficiency full-particulate-retention, passive catalytic regeneration or backpulse regeneration; (2) Scale-up of filter construction, catalyst impregnation methods, and testing; and (3) Single-filter, slip-stream tests at selected DoD user sites. Three types of filter were tested. The first was a backpulse-regenerable, compact, ceramic filter capable of reducing particulate concentrations to $PM_{2.5}$ compliant levels. The second was similar to the first except that an oxidation catalyst was deposited on and within the pore structure in order to simultaneously remove gaseous pollutants such as VOCs and CO. The third filter type was similar to the first except that an oxidation catalyst for removal of organic particulate was deposited on the surface of the membrane coating. This catalyst would passively regenerate the filter by oxidizing the filtered particulates, thereby eliminating the need for backpulsing. After the development of prototype filters, field tests were conducted to demonstrate the efficacy of removing particulates, VOCs and CO from selected gas streams.

BENEFIT: The DoD and Department of Energy (DOE) need new, cost-effective technologies to comply with the proposed, more stringent EPA standards for particulate matter as small as 2.5 microns ($PM_{2.5}$) for sources such as jet engine test cells (JETC), diesel engines, generators, incinerators and steam boilers. If effective, the proposed filters will bring a unique combination of particulate removal capability ($PM_{2.5}$ compliant), temperature resistance (900 °C), and compactness (more than any other competitive filter) with the ability to be catalyzed for simultaneous collection and destruction of organic particulate and gaseous pollutants.

ACCOMPLISHMENTS: Membrane coating formulation and casting process has been developed that results in high particulate retention on in-house tests and meets the gas flow pressure drop criteria. Membrane coating processes have been scaled up to prototype full-sized supports. Membrane-coated filters were treated with both commercial (Prototech Company) and CeraMem developmental soot oxidation catalysts. Filters similar to those tested for soot oxidation were tested for carbon monoxide (CO) and toluene oxidation. The test results indicate that the catalyzed filters were active for CO and toluene oxidation.

TRANSITION: The proposed ceramic filter technology will yield a Best Available Control Technology (BACT) for specific operational niches such as confined spaces, high temperature duty, and simultaneous removal of particulates, VOCs, and CO, with the potential for additional downstream nitrogen oxide destruction. The transition plan includes licensing the technology to filter manufacturers.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduction of Particulate Emissions from Jet Engine Test Cells Using an Annular After-Reactor; CP-1126

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Norman L. Helgeson; Naval Facilities Engineering Service Center – Port Hueneme, CA

FY 2002 FUNDS: $200K

DESCRIPTION: This project will develop a prototype Annular After Reactor (AAR) jet-engine attachment to reduce particle emissions from jet engine test cells (JETC). The AAR, positioned in the flow path of the jet engine exhaust tube, is simply a hollow pipe which delays mixing of exhaust gases with the surrounding air stream for a sufficiently long residence time to permit incineration of the particulate matter (PM), up to 90%, with minimum pressure drop. With a slight modification, the system may also be adapted for removal of NO_x, CO and unburned hydrocarbons.

The project will be carried out in four phases: (1) analytical and computer studies to refine the basic AAR fluid dynamics model and establish design criteria for field tests; (2) intermediate-scale field testing to complete the AAR design; (3) full-scale AAR system fabrication and field testing at a California Naval Air Station; and (4) data reduction and analysis to provide the recommended AAR system for PM reduction. The most challenging technical aspect of this study will be the efficient and rapid mixing, and combustion, of the injected natural gas within the AAR to achieve a proper temperature profile. Excessive pressure drops are expected to be eliminated by using a jet exhaust diffuser on the inlet to the AAR. The challenges of non-steady operating conditions will be addressed by using a feed-forward control system to make required AAR adjustments in concert with programmed changes in engine operating conditions. By maintaining the temperature of the exhaust gases within the AAR at 2000 °F, it is believed the generation of nitrogen oxides within the AAR will be insignificant.

BENEFIT: The DoD and DOE need new, cost-effective technologies to comply with the proposed, more stringent EPA National Ambient Air Quality Standards (NAAQS) for particulate matter below 2.5 microns ($PM_{2.5}$) for sources such as JETCs, and future National Emission Standards for Hazardous Air Pollutants (NESHAP) specific to JETC emissions. If demonstrated to be effective, the AAR is a minimum-capital-cost, minimum-operating cost approach for reducing PM emissions from JETCs.

ACCOMPLISHMENTS: Sub-scale testing (1.5" diameter jet exhaust) of the AAR, its combustor, and the fluid and thermal design was completed. Many additional tests were also conducted to evaluate using the AAR for the selective non-catalytic reduction of nitrogen oxide emissions. Previous sub-scale testing had demonstrated the potential of using the AAR for jet engine noise attenuation.

Based upon the sub-scale results obtained, hardware designs for small-scale testing (4.0" diameter jet exhaust) have been completed and fabricated, and the test site at the Point Mugu Naval Weapons Station has been modified for conducting both small-scale and intermediate-scale (12." diameter jet exhaust) tests. Some noise attenuation has also been realized. Small- and intermediate-scale tests to demonstrate the reduction of PM2.5, NO_x emissions from jet engines during stationary testing will be completed during the spring / early summer of 2002.

TRANSITION: The Army, Navy and Air Force have each expressed an interest in application of this proposed technology. In addition to JETCs, this technology has the potential to transition to other stationary and mobile sources of combustion emissions.

PROJECT SUMMARY

PROJECT TITLE & ID: Thermal Actively Controlled Sludge Treatment; CP-1132

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Tim Parr; Naval Air Warfare Center – China Lake, CA

FY 2001 COMPLETED PROJECT

DESCRIPTION: This project proposed a system to address the sludge disposal problem onboard Navy ships by using a unique, highly compact and high performance combustion process. The project's objective was to develop a two-stage incineration process comprising: (1) a primary vortex containment combustion (VCC) process, which also separates and retains particulates; (2) a self-propagating, high-temperature synthesis (SHS) thermal processing and encapsulation process for treatment of resultant ash; and (3) an actively controlled and monitored after-burner (AB) process for emissions reduction. The process can be automated and integrated into a comprehensive, continuously operated, oily water treatment system.

The technical approach built on the compact, closed-loop controlled waste incinerator for blackwater successfully developed in previous SERDP projects CP-034 and CP-887. The project consisted of six developmental phases: (1) fundamental laboratory-scale studies (injection, swirl design, flame stability, laser diagnostics, modeling, ash treatment) on surrogate sludge waste mixtures; (2) VCC and AB integration schemes; (3) conceptual design; (4) scale-up and testing of practical embodiments under full-scale conditions; (5) integration of monitoring and automatic active control schemes; and (6) testing requirements definition for future transition to a demonstration/ validation program.

BENEFIT: The Department of Defense (DoD) currently makes wide use of oil/water separators (OWS) to remove oil from a variety of aqueous waste streams prior to discharge. On-site or shipboard methods to treat or reduce the volume of accumulated sludges generated by these OWSs are required to eliminate sludge transportation costs for offsite disposal, to reduce downtime for maintenance, and to increase separator efficiency. The Navy is spending about $24M per year to treat 1 billion gallons of bilge oil which includes its storage, off-loading, on-shore treatment, transportation, and off-site disposal. This technology could significantly reduce costs with on-site disposal, either on shore facilities or, for larger vessels, on-board ship. Other advantages of on-site disposal include the increasing costs of off-site disposal, reducing assumed liability of third party disposal, eliminating waste handling and transportation, and avoiding costs for improper field disposal.

ACCOMPLISHMENTS: The integration tests with Golar 500 and the actively controlled afterburner of the CP-887 project on compact waste incineration were completed successfully. The British Thermal Unit waste throughput of the off-the-shelf Golar was increased by a factor of three and the carbon monoxide emission was reduced by a factor of nine. This understanding of the technology was instrumental in the design and fabrication of the VCC/AB in the present project. The VCC Laboratory Combustor was designed, fabricated, and assembled. Gaseous fuel combustion characteristics have been established for varying operational conditions.

TRANSITION: The user community was involved throughout the development and transition of the proposed work. Navy organizations, and the Army and Air Force have also expressed interest in the new sludge treatment system for potential application to a Deployable Waste Disposal System.

PROJECT SUMMARY

PROJECT TITLE & ID: Purification of Oily Wastewaters by a One-Step Advanced Biodegradation Process that Produces No Secondary Wastestreams; CP-1136

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Harris Gold; Foster-Miller, Inc. – Waltham, MA

FY 2001 COMPLETED PROJECT

DESCRIPTION: The overall objective of this project was to demonstrate a low maintenance biological process for onboard treatment of bilge water to meet the 15 ppm International Maritime Organizations Marine Pollution Convention (MARPOL) oil discharge provision and in which the oil contaminants are completely degraded to carbon dioxide and water.

A new technique, called forced molecular evolution, was used to cultivate enhanced optimized microorganisms needed for a robust, high throughput biological process with performance, size and maintenance characteristics suitable for shipboard deployment. The method had two steps: (1) a whole-cell, mutagenic selection technique to rapidly cultivate broadly non-specific bacterial strains tailored to the pressures imposed by the wastewater, and (2) a genetic enhancement technique to further optimize and tailor the degradation capability of the selected bacterial strains.

BENEFIT: The immediate environmental benefit derived from this program is the development of a new technology platform that is applicable to a widely diverse set of Department of Defense (DoD) and industrially related environmental problems. The methods and designs that will be developed are immediately applicable to current DoD needs. At the conclusion of this project, microbial consortia will be available for the treatment of bilge water and for wash rack and wash down waters from DoD maintenance facilities.

ACCOMPLISHMENTS: Sequential Batch Reactors (SBR) biomass sample were plated on Luria-Bertain (LB) agar (105 cfu/mL). Selected colonies are being identified by the Biolog (TM) ID system. Ten clones have been sequenced from the SBR biomass. Inocula from the defense fuels depot at Craney Island, Virginia, were received and used to initiate enrichment cultures to obtain organisms capable of degrading organic material from bilge water. At Tufts University, genetic enhancement data bases have been assembled on all of the well-characterized catabolic plasmids that likely would be involved in the degradation pathways for the organic components of oil.

TRANSITION: Project terminated due to lack of technical progress.

PROJECT SUMMARY

PROJECT TITLE & ID: Distribution and Fate of Energetics on DoD Test and Training Ranges; CP-1155

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Judith Pennington; U.S. Army Corps of Engineers Engineer Research and Development Center, Environmental Laboratory – Vicksburg, MS

FY 2002 FUNDS: $1050K

DESCRIPTION: The primary objective of this project is to provide DoD with techniques to assess the potential for groundwater contamination from residues of high explosives at testing and training ranges. Determining the concentration of post blast residues will focus on identifying the appropriate analytes for various range firing activities, identifying major sources of explosives contamination, and overcoming the large spatial variability in the distribution of contamination on ranges. The effects of munition type, range activities, and geographical and climatic conditions will be evaluated by sampling on ranges located at various sites across the country. The extent of contamination from higher order detonations will be determined by sampling impact craters on active ranges and by conducting detonations on pristine snow. The extent of contamination from various degrees of low order detonations will be determined by creating low order detonations under controlled conditions where full recovery and analysis of contaminants is possible. Once the composition of post-blast residues is determined, environmental transport parameters will be developed and the distribution and concentration of the residues at ranges will be estimated. These data can be used to estimate site-specific source terms for use in risk assessment and fate and transport models.

BENEFIT: Project results will document activities at test and training ranges that have the potential to cause groundwater contamination by residues of high explosives. Immediate benefits will include guidance for characterizing contamination, tools for anticipating the potential for environmental impacts and for demonstrating responsible management of facilities to sustain their use for testing and training. These methods could result in substantial cost saving for site characterization, and sustained use.

ACCOMPLISHMENTS: Surface soils have been sampled on heavy-artillery ranges at three U.S. installations and one Canadian installation. Samples have been collected at firing points and on hand grenade ranges, as well. Groundwater was sampled when monitoring wells were available; otherwise, surface water in the vicinity of the ranges was sampled. Tentative results suggest that range management should include removal of low order detonations, which potentially serve as point sources of contamination. Results also suggest that soils on hand grenade ranges may require periodic remediation. Kinetics and sorption process descriptors were determined for nitroglycerin, 2,4- and 2,6-dinitrotoluene, 1,3,5-trinitrobenzene, 1,3-dinitrobenzene, and the three transformation products of RDX, MNX, DNX, and TNX (funded jointly with EQT Program). Determinations of site-specific process data for TNT, RDX, and HMX in Fort Lewis soils were completed. A technical report was published titled: "Evaluating the Use of Snow-covered Ranges to Estimate the Explosives Residues that Result from Detonation of Army Munitions".

TRANSITION: Programs in place at all of the performing organizations will facilitate future widespread application of the procedures to determine the distribution and fate of energetics on DoD test and training ranges. Researchers at the U.S. Army Corps of Engineers ERDC Environmental Laboratory and CRREL, as well as Sandia National Laboratory (SNL) are actively involved in developing procedures to assess the fate and transport of explosives from UXO. The research team has been advising the National Guard on the complex problems with explosives at the Massachusetts Military Reservation. A demonstration program under the Environmental Security Technology Certification Program (ESTCP) can validate guidance with on-site evaluation and modeling that are developed in the proposed project with which ERDC and SNL have prior experience.

PROJECT SUMMARY

PROJECT TITLE & ID: Determining the Fate and Ecological Effects of Copper and Zinc Loading in Estuarine Environments: A Multi-Disciplinary Program; CP-1156

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Bart Chadwick; Space and Naval Warfare Systems Command – San Diego, CA

FY 2002 FUNDS: $532K

DESCRIPTION: The objective of this work is to produce a method for estimating the impact of copper and zinc loading in estuarine environments. Copper and zinc species are incorporated in a hydrodynamic (physical) estuarine model that simulates the principal estuarine topography, tidally-driven currents, meteorology, and bottom characteristics. The model is used to compute water residence times in the estuary, the key physico-chemical variable against which all other rate-dependant processes are evaluated. Steady-state concentrations of metal species, including the steady-state concentrations of the "free" hydrated metal ion are computed from the hydrodynamic model, using known or experimentally measured input and sedimentation data for the estuary. The computed steady-state concentrations of copper and zinc species are then compared to the experimental data and the model is fine-tuned by adjusting interspecies reaction (rate) constants, until the model is optimized to reproduce the copper and zinc dynamics. The environmental impact of the steady-state concentrations of the toxic copper and zinc species are evaluated in laboratory tests, as well as through field observations. The principal investigators from this project is collaborating with the other two SERDP projects on copper and zinc in estuarine system (CP-1157 and CP-1158) and with other Navy projects working in this subject area in an effort to foster close cooperation and exchange of information. In addition, the three SERDP projects will develop unified sampling and analysis techniques.

BENEFIT: This program will benefit the Department of Defense (DoD) and broader environmental compliance by: (1) the methods and data developed will be important to the DoD Uniform National Discharge Standards Program (UNDS); and (2) the information from this project will be transitioned to DoD environmental managers dealing with facilities and dredging compliance issues. The science resulting from the project should provide a basis for DoD to work with Environmental Protection Agency (EPA) in developing water quality criteria which account for the importance of metal species and complexation on toxicity. Finally the scientific approach developed under this program can be used as a model for supporting development of reasonable criteria and standards for other metals and contaminants.

ACCOMPLISHMENTS: The San Diego Bay was mapped for copper/zinc and copper species along with a broad range of potential controlling parameters including temperature, salinity, chlorophyll a, pH, and dissolved oxygen. Discrete samples were collected for additional analysis of complexation capacity, organic carbon, particulate matter, and microbiology. The sampling was carried out in close coordination with other SERDP investigators. An improved micro-volume technique was initiated for toxicity testing of the sand dollar larvae. This increases the number of samples and reduces the processing time, thus improving the ability to identify the relationship between toxicity and complexation capacity. The 1-D model validation was carried out based on field results. Work on sediment profiling and fluxes continued at two stations in the bay. Porewater and flux measurements were carried out at two stations in San Diego Bay. Initial runs for the 2-D model were carried out for total copper.

TRANSITION: The products of this project will be transitionable to the Environmental Security Technology Certification Program with proposed joint funding from the Navy. Technology transfer will be through peer-reviewed journals, technical reports and symposia. A workshop was held in Nov. 2000, co-sponsored by the Navy Applied Research 6.2 Program, to address copper and zinc technical and regulatory issues.

PROJECT SUMMARY

PROJECT TITLE & ID: Speciation, Fluxes, and Cycling of Dissolved Copper and Zinc in Estuaries: The Roles of Sediment Exchange and Photochemical Effects; CP-1157

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Stephen Skrabal; University of North Carolina – Wilmington, NC

FY 2002 FUNDS: $112K

DESCRIPTION: The goals of this study are to: (1) quantitatively determine water column concentrations and benthic fluxes of total dissolved (TD) copper (Cu) and zinc (Zn), dissolved Cu- and Zn-complexing ligands, and ancillary parameters at two sites in the Cape Fear Estuary, NC; (2) determine changes in cycling, fate, and organic speciation of dissolved Cu and Zn that may occur during resuspension events, focusing on the role of photochemical reactions; and (3) examine the effects of a large-scale dredging project on the speciation, fate, and cycling of Cu and Zn in estuarine waters and sediments.

Sediment and water sampling are conducted primarily at two sites, each of which are subject to shipping and berthing activities representative of Department of Defense (DoD) harbor facilities. Water column samples at the surface (~2 m depth) and near the bottom (1-2 m above the sediment surface) are collected and filtered in the field using a clean pumping and filtration system. Benthic fluxes of TD Cu and Zn, dissolved Cu- and Zn-complexing ligands, and dissolved organic carbon (DOC) are measured using a core incubation technique. Controlled photolysis experiments will be performed on sediment suspensions.

The principal investigators from this project is collaborating with the other two SERDP projects on copper and zinc in estuarine system (CP-1156 and CP-1158) and with other Navy projects working in this subject area in an effort to foster close cooperation and exchange of information. In addition, the three SERDP projects have developed a unified sampling and analysis techniques.

BENEFIT: The proposed project will provide a large number of direct measurements of benthic fluxes of Cu and Zn and their complexing ligands, and quantify the contribution of benthic fluxes to the amount of complexed Cu and Zn and of Cu- and Zn-complexing ligands in harbor waters. This project uniquely proposes an examination of photochemical effects on Cu and Zn speciation in estuaries and harbors. The results of this project can be used to develop scientifically-based standards for Cu and Zn in the aquatic environment.

ACCOMPLISHMENTS: The first-year analyses for both water sampling and benthic flux determinations have been completed. Several experiments on the role of copper complexes on photochemical reactions in organic-rich Cape Fear water have been conducted and results are being published. Collaboration continues with both the SPAWAR-San Diego (CP 1156) and University of Wisconsin-Madison (CP 1158) groups on benthic flux comparisons, sources of ligands, and Zn and Cu benthic fluxes. After initially concentrating on establishing methodologies for Cu speciation and fluxes, Zn fluxes and speciation are now being considered.

TRANSITION: The data presented by this project will provide information on the potential amelioration of Cu and Zn by dissolved organic ligands in harbors and estuaries. This data can be used by DoD to evaluate water quality compliance criteria that are based on environmentally relevant impacts of metal discharges, and hence to ensure that economic resources devoted to environmental monitoring and compliance are most efficiently utilized.

PROJECT SUMMARY

PROJECT TITLE & ID: Speciation, Sources, and Bioavailability of Copper and Zinc in DoD Impacted Harbors and Estuaries; CP-1158

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Martin Shafer; University of Wisconsin – Madison, WI

FY 2002 FUNDS: $375K

DESCRIPTION: The overall goal of this project is to advance the current understanding of the fate and impact of copper and zinc in harbors and estuaries. Specifically, the project develops a quantitative understanding of the speciation, bioavailability and fate of important metal species transported to and found within Department of Defense (DoD)-impacted harbors. The objectives of this project are to: (1) apply and refine methods for speciation of copper (Cu) and zinc (Zn) in harbor and estuary waters; (2) assess the influences of environmental factors and processes on the speciation and fate of Cu and Zn; (3) interpret experimentally determined lability estimates of dominant metal-complexes in terms of time scales relevant to biological and physical processes in DoD impacted harbors; (4) compare modeled estimates of bioavailability of specific phases with biochemically determined exposure on experimental organisms; and (5) determine sources of Cu and Zn to harbors and estuaries using a multi-faceted approach of selective sampling, metal phase discrimination, and unique stable isotopic signatures to distinguish DoD sources of Cu and Zn from other sources to harbors and estuaries.

By isolating functionally distinct metal "pools" within harbor systems, the lability of Cu and Zn within these pools can be characterized. The nature and sources of ligands in specific pools are determined by chemical and biochemical means. Measurements of liability in specific pools, as defined by chemical and physical speciation techniques are complemented and validated by bioassays at both the molecular and organism level. Stable isotopes of Cu and Zn will be explored as tracers of source and source specific bioavailability.

The principal investigators from this project is collaborating with the other two SERDP projects on copper and zinc in estuarine system (CP-1156 and CP-1157) and with other Navy projects working in this subject area in an effort to foster close cooperation and exchange of information. In addition, the three SERDP projects have developed unified sampling and analysis techniques.

BENEFIT: These findings will allow the development of a method for the assessment of the potential of Cu and Zn to impact biological communities. This work, therefore, will have direct bearing on the establishment of water quality criteria in these systems. This study will provide a crucial test of the applicability of stable isotopes to aid in source reconciliation and bioavailability studies. Important parameters will be established from which the precision of source assignment can be assessed. Source tracing and apportionment using stable isotopic signatures should have broad applicability to both aquatic and terrestrial DoD sites and the exploratory work in this study will provide that assessment.

ACCOMPLISHMENTS: Functionally distinct metal pools within the three contrasting harbor/estuarine study systems (San Diego Bay, Norfolk Harbor and Cape Fear, Wilmington) were isolated and characterized. The lability of Cu and Zn within these pools was determined using several complementary techniques, including electrochemical and resin-based methods. Bioavailability of Cu in specific pools was determined with three species of marine algae using both molecular and whole organism bioassay endpoints.

Major advances were made in the development of several key new techniques/technologies: (1) An instrumental technique for ultra-high precision stable isotope analysis of copper using a multi-collector, magnetic sector, inductively-coupled plasma mass spectrometer (MC-MS-ICPMS); (2) Bioassays techniques for the assessment of available/labile species of Cu using three species of marine phytoplankton; (3) An extremely sensitive method for the quantification of a metal stress protein (phytochelatin 2 and 3); and (4) An automated method for the analysis of Cu and Zn in seawater using solid- phase chelation and quadrupole ICP-MS.

TRANSITION: The technology underpinning the method of assessing the potential of Cu and Zn to impact biological communities should be readily transferable to DoD or DoD contractors. Data developed on Cu and Zn sources to, and within, the study systems will be used to construct or refine mass balances of metal loading. When coupled with information generated from this study, on source specific metal availability, appropriate resources can be directed to controlling inputs with the greatest potential for ecosystem impact. Recommendations along these lines will be prepared for DoD, which may then use these data in future permitting applications. DoD can use information from this project to determine whether stable-isotope technology should be applied to other impacted sites.

PROJECT SUMMARY

PROJECT TITLE & ID: A Predictive Capability for the Source of Terms of Residual Energetic Materials from Burning and/or Detonation Activities; CP-1159

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Zhang; Aerodyne Research, Inc. – Billerica, MA

FY 2002 FUNDS: $191K

DESCRIPTION: The overall goals of this project are to: (1) understand and quantify the major chemical and physical processes, such as afterburning effects, and formation and deposition of particles; (2) develop a Source Characterization Model (SCM) for predicting accurately the source terms resulting from the burning and detonation of munitions, including both gaseous and particulate species; (3) link the SCM output to appropriate fate and transport models in air, soil, or water medium; and (4) validate the final SCM against a few typical scenarios. This project is developing the SCM and related databases and linking them to available dispersion and transport models. The input to the SCM includes munitions or energetic identity and weight, ambient site conditions, and site-specific conditions for the open burn/open detonation (OB/OD) or use of munitions. The SCM includes algorithms, supporting databases, and a graphical user interface for the prediction of chemical identities and emission factors, particle size and deposition, plume buoyancy, and plume size at final rise. The output of the SCM is used as input conditions to existing transport and dispersion models in air, water, and the ground surface.

BENEFIT: The estimated benefits to the Department of Defense (DoD) are cost reduction by modeling and cost of incomplete responses to regulatory concern. The total cost of emission characterization by testing for an estimated 400 unique munitions could cost DoD from $0.5 billion to $1 billion. Assuming that only 1 in 20 munitions requires testing and the rest can be modeled, the savings from modeling could exceed $475 million. Typically an installation may spend up to $2 million monitoring groundwater and sampling soil in order to satisfy regulators and the public that munitions use or OB/OD has no impact to human health or the environment.

ACCOMPLISHMENTS: SCM model test runs based on the primary energetic materials for each ordinance were performed. Concurrently, further model development focused on the inclusion of particle interactions in the detonation plume, as well as soil interactions during detonation and in the plume. Algorithms for treating particle microphysics were incorporated into the SCM model. The effect of soil depletion (the fall-out of particulate matter) to the plume dynamics has been formulated. Modifications to the mass balance, momentum equation and energy balance were made. The meteorology module, used to compute various properties for the ambient atmosphere, was coupled to a general-purpose flow module for processing of the thermodynamic properties and chemical composition of one-dimensional flows. The source module, which controls specification of initial chemical speciation and puff thermodynamic properties for a given detonation, was linked to the soil interaction module in helping to estimate the released soil mass. Routines for treating finite-rate chemical kinetics were developed and integrated into the plume dynamics module. A dry and wet deposition component was integrated into the plume dynamics model, as well.

TRANSITION: The modeling capability developed by this project will be a public domain environmental assessment model. It will be reviewed for acceptance by applicable EPA offices involved in emissions modeling. Subject to EPA approval, it will be made available through the EPA regulatory support electronic bulletin board. The project results will be presented to potential users via journal articles, symposia, and technical reports. The potential users include all DoD, DOE, and EPA activities involved in OB/OD.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of $PM_{2.5}$ Dust Emissions from Training/Testing Range Operations; CP-1190

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Veranth; University of Utah – Salt Lake City, UT

FY 2002 FUNDS: $238K

DESCRIPTION: This project is conducting field measurements and laboratory analyses of windblown dust and road dust resulting from troop operations at arid sites in the western United States. The goal of this study is to provide installation-level environmental staff with scientifically validated information for developing emissions inventories, environmental assessments, and cost-effective dust control measures that are compatible with mission readiness. Source samples, laboratory analysis of these samples, development of advanced sample analysis techniques, theoretical modeling, and measurement of field emissions and receptor site particulates constitute the major components of this study. The study is based on two hypotheses developed from previous studies of dust emissions in arid climates. Only a small fraction of the dust that is initially suspended is actually transported long distances. Dust emissions from various sources potentially contain marker species that are present at higher concentrations than the regional background, and these markers can provide sensitive methods for quantifying the contribution of various source categories to the particulate collected at receptor sites. The experimental program tests these hypotheses with an integrated program of sampling dust at multiple locations and elevations above grade during selected troop operations on unpaved roads or cross-country trails.

BENEFIT: The direct products of this study will include (1) a critical evaluation and review of source characterization, dust emission inventory, and transport modeling technology applicable to training/testing range operations, and (2) technical papers regarding field measurement, sample analysis, and data reduction methods. Based on the detailed sampling and analysis in this study, specific recommendations will be made regarding appropriate methods for routine use in dust characterization studies.

ACCOMPLISHMENTS: A user advisory panel representing state air quality planning/modeling staff, air quality engineering consulting, and installation-level environmental staff has been recruited and members have provided input on the project plan. A source area soil sampling plan has been developed. The plan considers potential for vehicle and wind entrainment of dust, proximity to Class I air quality areas, geology and soil classifications, and is designed to maximize the differences in chemical speciation and particle morphology. Field sample collection was initiated. Existing samples and analytical data collected by Watson and Chow have been inventoried. Analysis of samples has been initiated and results from the initial particle analysis will be used to guide the remaining sampling. The study of possible improvements to computational modeling of dust entrainment, near-source deposition, and dispersion commenced. Field data collected by Veranth et al. in a related study have been analyzed and show the importance of considering atmospheric stability and small-scale thermal mixing in a model relating initial dust suspension to the source term for long range transport.

TRANSITION: The direct products of this study will include a critical evaluation and review of source characterization, dust emission inventory, and transport modeling technology applicable to training/testing range operations and technical papers regarding field measurement, sample analysis, and data reduction methods. This technology will be transferred to potential users by the investigators and by members of an advisory panel.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterizing and Quantifying Local and Regional Particulate Matter Emissions from DoD Installations; CP-1191

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Gillies; Desert Research Institute – Reno, NV

FY 2002 FUNDS: $360K

DESCRIPTION: Military activities on Department of Defense (DoD) installations in the southwest U.S. are potentially large contributors of wind-blown dust due to the presence of large expanses of fragile desert soils and via testing and training activities. Particulate Matter (PM) emitted by these activities impacts vehicle performance, and threatens the health and safety of military personnel due to inhalation of PM and loss of visibility. This project proposes a systematic, empirically based research approach that combines environmental monitoring and field experimentation to quantify and characterize PM emissions from testing and training.

Contributions from dust and other sources is measured during a 1-year ambient air quality monitoring program at upwind and downwind boundary flux sites, combined with 14 days of intensive monitoring during periods of active training. An emission factor database is developed using upwind-downwind monitoring methods to measure vehicle-generated emissions using fast-response instrumentation. Potential long-range transport of the emitted PM will be assessed from field experiments. Potential visibility degradation off-post is determined with an intensive field measurement campaign.

BENEFIT: Specific benefits from the research include: (1) the development and demonstration of a methodology that will identify contributions of PM from specific on-post sources to the flux of PM exiting installation boundaries; (2) the development and demonstration of a methodology to define emission factors for military vehicles and an emission factor data base that can be used in a model to estimate the contributions from different sources within an installation for various testing and training scenarios; (3) a model to convert the horizontal emission flux to vertical emission flux that will allow the emission inventory data to be utilized in dispersion models to estimate the long-distance transport potential of the emitted PM; (4) the demonstration of the TRAKER approach to determine horizontal emission fluxes and its effectiveness to map the emission potential of different surface types with great economy, and (5) characterize and quantify the emissions from the military activities.

ACCOMPLISHMENTS: Three vehicle types (tank, tracked fighting vehicle, and Humvee) were used for testing on Ft. Bliss. Instrumented towers were deployed to measure dust fluxes to calculate vehicle emission factors and the downwind relationship between horizontal and vertical flux. Soil samples for sedimentological analyses were collected. Simultaneous upwind-downwind measurements were collected and the vehicles were instrumented with TRAKER to measure the plume concentrations and particle size distributions. These data were evaluated and the relationship between plume characteristics and the estimated vehicle emission factors was analyzed. Wind tunnel testing and soil sampling for estimating vertical dust flux and soil property characterization were completed. Dust generation varies with soil conditions, type of vehicle, and wind conditions giving a complex result to understanding and modeling dust movement.

TRANSITION: The acquired information can be transitioned to Integrated Training and Management (ITAM) personnel who may be given the mandate to deal with certain aspects of the dust and PM emission problem.

PROJECT SUMMARY

PROJECT TITLE & ID: Fundamental Studies of Air Emissions from DoD Munitions and Novel Approaches for Their Detection; CP-1193

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Brill; University of Delaware – Newark, DE

FY 2001 COMPLETED PROJECT

DESCRIPTION: DoD must consider the potential occurrence of Toxic Release Inventory (TRI) air emissions from munitions at testing and training ranges on land and sea. This is a major challenge since there are hundreds of chemicals on the TRI list and emission characterization of DoD munitions, such as from firing and exploding ordnance is very difficult and expensive. The hostile environment that is presented by an actual weapon firing precludes the real-time measurement of TRI emissions throughout the whole flowfield using present technology. This project generated a fundamental understanding of the reaction chemistry of munitions by understanding the actual reaction chemistry resulting from mixing with ambient air, thus identifying the major chemical pathways and classes of TRI compounds that are possible. Firing point emissions were characterized by the capture, identification, and analysis of multiple emissions from small arms, tank cannons, howitzer cannons, mortars, rockets, etc using a specialized test facility. The experimental approach tested nitrocellulose (NC), nitroglycerin (NG), octagen (HMX), and pentaerythytol tetranitrate (PETN) with respect to their pyrolysis differences in an inert (Ar) and a reactive (air) atmosphere. The effect of different amounts of water vapor in air was explored. This information was obtained from T-jump/FTIR spectroscopy in which fast controlled heating of a material can be achieved.

BENEFIT: The experimental work produced a fundamental understanding of the effect of the surrounding atmosphere on the pyrolysis processes and to provide input for parameterizing the computational fluid dynamics (CFD) model of the time evolution of the chemical plume at the muzzle. The long-term benefit of this project is the development of hardware and related models that can be used to identify and characterize TRI emissions from DoD munitions in real-time and in the open field is the primary benefit of this effort. Other benefits include the identification of classes of emission factors as a function of source type and the assessment and understanding of temporal and spatial variability of the emissions.

ACCOMPLISHMENTS: A simulated air atmosphere generator was built and flash pyrolysis of NG, HMX and PETN in air and argon were performed. Differences in the pyrolysis chemistry of nine relevant energetic materials in air and argon were described in a published report. The CFD effort was coupled with a thermochemical equilibrium high-pressure ballistic cycle code (already developed), the constant breech pressure gun (CBP), using the thermodynamic equilibrium program BLAKE. This provided the muzzle species, temperature, and pressure starting conditions for the CFD code as a function of specific gun type and propellant used. The NSRG code was modified to accept initial conditions at the muzzle including gas composition (species), density, temperature, and velocity. The BLAKE and NSRG codes were merged and finite kinetics for the conversion of NO to NO2 in the boundary layer were added. An accounting for relevant chemical species from the gun muzzle exhaust was made in the CFD code: 33 species were included. A representative CFD example case was run (assuming equilibrium) for the muzzle exhaust flowfield.

TRANSITION: The main product of this research is a much better understanding of the chemical pathways that may or may not result in the formation of TRI emissions for various classes of munitions/source types The emissions data created can be used to feed fate, transport and effect models.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Scrap Metals for Mass Detonating Energetic Materials; CP-1194 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. James Phelan; Sandia National Laboratories – Albuquerque, NM

FY 2001 COMPLETED PROJECT

DESCRIPTION: This research project explored the concept of an automated screening process to help characterize scrap materials for the presence of mass-detonating energetic materials. The current practice of visually screening large amounts of scrap materials is inefficient and has misidentified mass detonating quantities of explosives causing significant equipment losses during scrap recycling operations. The concept of an automated screening process using chemical sensing technology has the potential to provide an efficient low cost method to discriminate whether scrap materials contain mass detonating quantities of energetic materials prior to entering a treatment process, and to verify decontamination of surface residues after treatment. The requirements for a chemical sensor for this application include high sensitivity and selectivity for the chemicals found in the energetic materials, and fast response time to allow real-time sorting. Using a novel amplifying fluorescent polymer (AFP) approach, the detection of TNT had been engineered into a sensor system by Nomadics, Inc. and researchers at MIT believe that they can design an AFP for RDX. The project proposed to complete proof-of-concept tests for determining mass detonating quantities of energetic materials. When successful, the magnitude of the vapor signature could be used to develop a conceptual design for a dynamic screening system. The research team determined the success of the technology by measuring and comparing the absolute sensitivity of the latest Nomadics sensor to vapors derived from water solutions and measured with preconcentrated samples. The team also performed bin tests and compared analyses from the Nomadics AFP sensor with the Tenax tubes or SPME samples, and extrapolated the data for use of the Nomadics AFP sensor in a dynamic conveyor system.

BENEFIT: This project determined the proof-of-principle of whether chemical vapor sensing could discriminate mass detonating energetic materials among scrap materials. If successful, this technology could be linked to conveyor belt sorting system to segregate portions of the scrap that likely contain mass detonating quantities of energetic materials, thereby, reducing the amount of scrap material requiring expensive inspection and treatment.

ACCOMPLISHMENTS: The amplifying fluorescent polymer sensor was tested with both soil and aqueous standards to determine the minimum detectable level for TNT and DNT. Estimate of the minimum detection limit for the FIDO was about 5 ppt for both TNT and DNT. Bin tests, consisting of wood crates filled with ordinary scraps of metal, wood, plastic and tires, demonstrated the utility of vapor sensing for cased and uncased detonable amounts of explosives. Other types of detonable cased explosives, such as aged and weathered UXO, would need to be tested to determine the viability of chemical sensing among scrap. Fused 81 mm mortar in a simple aluminum flux box (two aluminum baking pans) showed a very high response to the amplifying fluorescent polymer sensor.

TRANSITION: The opportunity to process large amounts of range scrap to eliminate mass detonating quantities of energetic materials may be feasible with a segmented gate system outfitted with a highly sensitive chemical sensor array for scrap processing. An extremely sensitive chemical sensor has emerged from basic research programs that can be adapted for use in the segmented gate system. This sensor has the potential to be used to test other objects as well.

PROJECT SUMMARY

PROJECT TITLE & ID: Development of a GIS-Based Complex Terrain Model for Atmospheric Dust Dispersion; CP-1195

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. K. Jerry Allwine; Pacific Northwest National Laboratory – Richland, WA

FY 2002 FUNDS: $370K

DESCRIPTION: This project characterizes dust emissions from range training/testing activities by: (1) analyzing existing dust characterization data; (2) conducting additional field studies, and (3) developing a geographic information system (GIS)-based complex-terrain atmospheric dispersion model. This modeling system has several uses including: (1) the near real-time tracking of dust movement given real-time meteorological data and dust generation information, (2) performing air quality assessments, and (3) planning and evaluating training operations and dust control measures under various meteorological scenarios. A primary focus of the proposed research is to develop dust emission factors for range activities and incorporate the dust emission formulations into a U.S. EPA approved air quality model. The GIS-based air quality model will be compatible with available military land management and operational models, and will be incorporated the effects of complex terrain on dispersion.

BENEFIT: The completed modeling system will allow military personnel to specify training/testing activities using a GIS interface, run the atmospheric dispersion model, and then graphically view the dust impacts using a GIS. The model will also have the capability to provide real-time dust dispersion for those sites maintaining real-time weather measurement data. This capability will allow graphic, GIS-based representation of current and projected PM transport and concentration that will enable military staff to modify activities or locations to minimize health and environmental impacts of airborne dust and/or obscurants. With the emphasis on user needs and input during the development of the model, transition to installation operation and use of the model should be greatly facilitated.

ACCOMPLISHMENTS: The design of the dust dispersion modeling system, the completion of the prototype modeling system, and a review of current dust emission formulations for activities at military training facilities were completed. A PNNL team of experts familiar with graphical user interfaces, the ArcView GIS, and atmospheric dispersion models reviewed applicable models and modeling components. They recommended the dust dispersion modeling system to consist of the Air Pollutant Graphical Environmental Modeling System (APGEMS) user interface coupled to ArcView, three existing atmospheric dispersion models (APGEMS and two EPA-approved models – CALPUFF and CALGRID), and a new dust emission module based on the review of dust emission formulations and future SERDP and other field studies. The CALPUFF and CALGRID atmospheric dispersion models have been acquired and have undergone initial evaluation for inclusion in the modeling system. The prototype modeling system consists of the APGEMS user interface coupled to ArcView and the APGEMS atmospheric dispersion model.

TRANSITION: The product (dispersion model and dust characterization techniques) will be transferred to military land managers and operational leaders for use during testing and training exercises and operation in order to reduce the generation of dust. The end product of this product will also include a field deployable time-tagged particle sampler and a documented measurement method for rapid, cost-effective assessment and mapping of roadway dust generation with high spatial resolution.

PROJECT SUMMARY

PROJECT TITLE & ID: Removal, Degradation, and Recovery of Energetics Residues from Range Scrap; CP-1196 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Philip Thorne; Applied Research Associates, Inc. – South Royalton, VT

FY 2001 COMPLETED PROJECT

DESCRIPTION: The objective of this research project was to investigate an exceptionally low-cost, simple, environmentally benign process to treat energetics residues in-situ on scrap materials of virtually any size or type found on training/testing ranges at DoD installations. The process relies on mild, base hydrolysis of energetics at ambient temperatures in a lime-water solution. Organic high explosives (HE) are degraded to non-hazardous inorganic ions and insoluble polymers that can be readily recovered from the aqueous decontamination solution by sedimentation or filtration.

Experimentation began with the simple lime-water solution (1lb of lime/100gal water) that was observed to dissolve and polymerize explosives in a previous study. Modifications to the basic lime-water solution were investigated in order to increase the dissolution rate of secondary HE. Test materials included TNT, RDX, HMX and mixtures thereof. Dissolution rates were determined visually. The goal was to understand the effect of temperature on dissolution, degradation and polymerization so that a formulation which is effective and predictable at all ambient temperatures in the field can be developed. A second element was identified and optimized conditions for the polymerization and precipitation of HE. Three types of contaminated scrap samples were prepared: (1) pieces of range scrap coated with HE; (2) HE loaded into small cracks and crevices; (3) HE encased in pieces of metal scrap. Dissolution and polymerization will be evaluated visually and by instrumental methods. The team developed a scrap treatment protocol based on the optimum lime-water formulation and perform a bench scale demonstration of it.

BENEFIT: The research team will establish feasibility for timely and effective treatment of a variety of critical energetics residues on range scrap using a lime-water formulation. Through a cost analysis performed at the end of the project, they will also have demonstrated that the new technology is more cost-effective than alternative approaches and therefore worthy of implementation at DoD and DOE sites containing "spent" shells and munitions.

ACCOMPLISHMENTS: The aqueous solutions of 75% SuperSolve/0.5% $Ca(OH)_2$ or 50% acetone without lime were determined to be capable of removing deposits of TNT and RDX from authentic range scrap in 48 hours with agitated soaking. TNT was partially de-nitrated and converted to a red polymer. RDX was completely degraded to release nitrite and organic acids. Partial recovery of polymerized TNT was possible from the acetone solution after liming, but not feasible from SuperSolve. The resulting solutions were readily decolorized using aerobic, activated sludge. Start-up and treatment costs were estimated. These estimates were largely dependent on load-capacity of the cleaning solutions.

TRANSITION: In collaboration with CRREL researchers and other independent evaluators, field demonstrations and validations of the technology will be performed at DoD sites. If the scrap treatment technology proves feasible, support will be solicited from industrial clients to further develop and adapt the technology to their cleanup needs.

PROJECT SUMMARY

PROJECT TITLE & ID: A Field Program to Identify TRI Chemicals and Determine Emission Factors from DoD Munitions; CP-1197

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Chester Spicer; Battelle – Columbus, OH

FY 2002 FUNDS: $961K

DESCRIPTION: At present, published emission factors for munitions activities have been focused on tests conducted for open burning and open detonation (OB/OD) disposal of energetic materials. DoD needs a technology that would allow emission factors for Toxic Release Inventory (TRI) chemicals to be developed for munitions usage during routine testing and training activities. The overall objective of this program is to demonstrate a methodology for measuring emissions of TRI chemicals from DoD munitions activities and facilities. Specific objective is to assemble and test an instrumentation package capable of measuring pertinent TRI chemicals at DoD sites. A second specific objective is to measure "point of discharge" TRI chemical emissions from a variety of munitions used in training activities. A third objective will be to measure "point of impact" TRI emissions from a wide range of DoD munitions at an outdoor testing range. The major focus of the project is the field campaigns, and the project will conduct two types of campaigns. One will focus on emissions from the discharge of weapons (point of discharge studies) and the other on emissions from explosion on impact (point of impact studies). The field campaigns are conducted at Aberdeen Test Center (ATC). The point of discharge campaigns make use of an indoor facility which permits firing weapons with capture of the discharge emissions. The point of impact studies are carried out at one of ATC's outdoor ranges.

BENEFIT: The proposed program is designed to work closely with DoD services to: (1) identify important munitions activities and sites; (2) use existing data and chemical principles to develop a list of target TRI chemicals that will be measured in the field; (3) recommend and deploy innovative state-of-the-art field monitoring technologies; and (4) collect real world data on munitions emissions for important munitions activities under a range of actual field conditions at field sites. These data will advance the state of knowledge of the nature and quantities of emissions from munitions activities and will help DoD meet its EPCRA reporting requirements by providing more accurate estimates through the DDS. In addition, the accurate characterization of emissions from these activities will assist DoD in setting priorities for emissions reduction strategies.

ACCOMPLISHMENTS: During FY 2001, this project focused on developing a list of target chemicals for emissions measurements (115 chemicals) and selecting the types of munitions (~ 14 different types) that should be included in the field campaigns. A literature review was conducted on munitions firing studies, exploding ordnance studies, open burning-open detonation studies, and bang-box tests. Selecting and optimizing sampling and analysis methods was completed in order to measure as many of the target chemicals as possible during the Point of Discharge and Point of Impact studies. Limited dispersion modeling was conducted under conditions appropriate for outdoor ranges, to estimate the concentrations of target chemicals at the point of sampling. The modeling results will help establish the detection limits that are required of the measurement methods. This information will be used to prepare the sampling plan for the Point of Impact tests. A lidar system for use in determining the dimensions of the emissions cloud was modified. Several approaches to estimate emission cloud dimensions were investigated.

TRANSITION: There is a broad interest within DoD in developing a credible method to measure the emission factors that are used to estimate annual emissions, and in applying the method to measure emission factors from significant munitions activities.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Corrosion - Potential Contamination Source; CP-1226

PRINCIPAL INVESTIGATOR & ORGANIZATION: Ms. Bonnie Packer; U.S. Army Environmental Center – Aberdeen Proving Ground, MD

FY 2001 FUNDS: $700K

DESCRIPTION: Minimum data exist on the condition of unexploded ordnance (UXO) in soils at military testing and training ranges. It is unknown whether rounds that enter the soil and do not explode are in pristine condition, have significant pitting and generalized corrosion, or whether some crack before they come to rest within the soil. Understanding the condition of the UXO casing will help to characterize the potential for UXO energetic fill material to move into and through soil at these testing and training ranges. The objective of this project is to identify the type, character, and rate of perforations in the casings of UXO underlying soil at U.S. military installations. The project characterizes the modes and rates of UXO casing perforation and the factors that govern those rates.

Field data from soil impacted by UXO is collected from six ranges actively undergoing clearance by the U.S. Army Corps of Engineers. Approximately 200 pieces of ordnance are studied in order to assess the relative impacts of various parameters on the degradation of ordnance casings. A database is developed for the 200 ordnance items as a permanent record of the field survey. These data are used to first understand ordnance corrosion processes and then to construct an analytical model for predicting time to perforation of ordnance in soil. The model is personal-computer based and allows the user to input metal thickness and specific soil characteristics (e.g., oxidizing/reducing, pH, soil classification). The output provides a prediction of years to perforation.

BENEFIT: The data collected and the model produced will allow decision makers to (1) use perforation size and shape and estimates of time-to-perforation to perform risk assessment calculations for movement of UXO fill chemicals into the surrounding soils, (2) mitigate release rates by altering those environmental parameters which may accelerate corrosion (e.g., soil pH), (3) focus cleanup resources on those ranges that have the greatest risk of energetic fill material transport into the environment, and (4) maintain troop readiness by training and testing on those ranges that do not pose significant risk.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION: This corrosion study is the first element of work necessary to understand and mitigate the risks associated with UXO energetic fill releases. The data and methodology that are developed by this project will be applied to specific range issues to determine appropriate management protocols.

PROJECT SUMMARY

PROJECT TITLE & ID: Measurement and Modeling of Energetic Material Mass Transfer to Pore Water; CP-1227

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. James Phelan; Sandia National Laboratory – Albuquerque, NM

FY 2001 FUNDS: $340K

DESCRIPTION: Ordnance detonation during military testing and training operations leaves unreacted energetic materials on and in near-surface soils. Transport of these energetic materials in soils is initiated by a mass transfer process to soil pore water. This project proposes to analyze this mass transfer process using laboratory measurement and numerical simulation to produce an energetic material source function linked to weather cycles. This effort will involve two phases of experimentation and model development. Phase I will consist of an initial series of experiments designed to determine the critical parameters affecting the mass transfer of energetic materials to pore water and the derivation of a mathematical function that incorporates the most significant factors. Phase II will evaluate in more detail the factors that have the greatest impact in mass transfer process and evaluate actual post-blast residue in soil obtained from test or training ranges. Mass transfer rate data will be collected in an unsaturated or saturated column test apparatus allowing variation in parameters representative of environmental condition in near surface soils. Actual range soil and post blast residue will be used to assess the accuracy of the mass transfer function.

BENEFIT: The inclusion of an energetic material source release function in a soil solute transport simulation code will create a new predictive ability to assess the migration potential of energetic materials left by military testing and training operations.

ACCOMPLISHMENTS: This project is a FY 2001 Late New Start. During FY 2001, Composition B (Comp B) explosive was obtained from McAlister Ammo Depot. The Comp B was processed into three size fractions: 100 um, 500 um and 1000 um to perform preliminary solubility kinetics tests. Phase I experiments, using saturated column flow apparatus with glass beads as the porous medium, tested variations of energetic material particle size, water flow rate and temperature. Water solubility tests were completed for RDX and Comp B from 10 to 40 C in both deionized and tap water. After developing test equipment a second series of tests was performed to measure the unsaturated flow properties of the glass beads, assembly of a vacuum box containing the fraction collector, construction/calibration of column tensiometers, and system integration. The diffusive distance-time function for mass leaving the surface of the energetic material and mobile-immobile partitioning has were modeled to account for patterns observed in the experimental data.

TRANSITION: Modelers can use this source release function as part of a solute transport simulation code to predict the fate and transport of energetic material in soil pore water. In addition, this work can be extended to evaluate groundwater impact and range management strategies by implementation through the Army Environmental Center.

PROJECT SUMMARY

PROJECT TITLE & ID: The Development of Spatially-Based Emission Factors from Real-Time Measurements of Gaseous Pollutants Using Cermet Sensors; CP-1243

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Natalia Meshkov; Argonne National Laboratory – Argonne, IL

FY 2002 FUNDS: $420K

DESCRIPTION: The Department of Defense (DoD) needs to identify and characterize emissions of trace air toxic compounds, especially persistent organic pollutants, from operations and activities at its facilities. This information is used to estimate emission factors used in environmental risk assessments. Currently, ambient air toxic concentration data for most urban air toxics (UATs) and mobile source air toxics (MSATs) are not available.

This project aims to (1) develop miniature sensors and portable sensor arrays capable of rapidly detecting and characterizing trace air toxic compounds in near-real time, (2) integrate pollutant data into spatial and temporal emission profile models correlated with specific DoD activities, and (3) produce high quality emission factors for targeted pollutants released during various activities. Cermet (ceramic-metallic) electrocatalytic "smart" microsensors that monitor emissions in near-real time will be used. These sensors are capable of operating over a wide temperature range (approximately -40 °C to 500 °C). Voltammetric analytical techniques employed during sensor operation allow for both a wide variety of gaseous constituents and a wide range of analyte concentrations to be detected (from parts per billion to percent levels). Advanced pattern recognition techniques are used to resolve composite signals from a mixture of gases into individual components. TiO_2 photocatalytic properties are used to develop new microsensors that complement voltammetric devices. By combining existing and experimental microsensor technologies, more capable comprehensive microsensor arrays (a micro-miniature electronic nose) for selected emission constituents are developed. The new microsensor arrays are used to efficiently produce improved emission characterization profiles associated with DoD activities and to estimate and validate emission factors.

BENEFIT: The project provides DoD new sensing systems for detecting and characterizing trace air toxic compounds. These systems are portable, small, and inexpensive. Operating from a laptop computer, these system can provide near-real-time analysis and feedback. UATs and MSATs, and spatial profile of air pollutants will be provided. The information gained from this project will advance the efforts for control of pollutants, the fate and transformation of pollutants, and transport modeling of pollutants.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: Results from this project will enable the identification and characterizing of the emissions of trace air toxic compounds produced from activities at DoD operations. Actual data from the research could be of direct interest of DoD facilities and to the U.S. EPA since future regulations will be based upon the results of this research effort. An effective transition plan will include constant contact with colleagues at EPA and DoD and marketing of the results at conferences and working groups of regulatory agencies.

PROJECT SUMMARY

PROJECT TITLE & ID: Harmful Algae, Bacteria, and Fauna Transported by Department of Defense Vessels; CP-1244

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. JoAnn Burkholder; North Carolina State University – Raleigh, NC

FY 2002 FUNDS: $250K

DESCRIPTION: Invasions of non-indigenous aquatic species are a recognized threat to the ecology of aquatic environments worldwide. Mitigation and control efforts along U.S. coasts have cost more than two billion dollars annually. Ballast water is thought to represent the primary vector of marine non-indigenous introductions in the U.S. and elsewhere. There is concern that existing and proposed regulatory measures designed to control such introductions could translate into severe restriction for DoD vessels, unless this aspect of ship operations is more fully characterized and managed.

In order to identify and quantify harmful or non-indigenous species of algae, bacteria, and microfauna (< 350 µm) transported via ballast water on representative DoD vessels operating from the U.S. Atlantic and Pacific coasts, samples will be collected at the Norfolk and San Diego Naval Stations during summer and winter. Plankton samples will be analyzed using phase contrast light microscopy. Scanning electron microscopy will be used for positive identification of species of particular interest. The potential of flow cytometry and molecular screens as rapid tools for identification and enumeration of selected taxa in ballast water will be investigated. The data are subjected to exploratory statistical analyses, followed by appropriate determinative measures to identify relationships between environmental or ship-related variables and the biological evidence. Species of taxonomic groups and harmful/noxious species discovered during the sampling surveys are exposed to various heat regimes in order to assess the efficacy of using excess engine heat as a control treatment.

BENEFIT: Results of this study will fill a critical data gap by providing information on the abundance and diversity of aquatic species found in ballast waters from DoD vessels. The characterization of communities in the ballast water of DoD vessels, including ‘harmful species,’ together with bench-scale heat treatment experiments, will assist the DoD in determining the measures necessary to reduce the risk of non-indigenous introductions to U.S. harbors and estuaries by ballast water. This project is coordinating these research efforts with CP-1245.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: Results from the proposed research will support the activities of the Unified National Discharge Standards (UNDS) program. This program, managed jointly by DOD and the Environmental Protection Agency, is intended to analyze discharges from DOD vessels, and develop performance standards for pollution control devices that may be employed to treat these discharges. Non-indigenous species have been identified as a constituent of concern for several of the discharges examined. The data we obtain will guide the formulation of scientifically-defensible treatment standards under the UNDS program, and the development of effective pollution control devices, by providing information on the abundance and types of organisms found in ballast water and as fouling on hulls.

PROJECT SUMMARY

PROJECT TITLE & ID: Characterization of Aquatic Non-Indigenous Species for Department of Defense Vessels; CP-1245

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Eric Holm; Naval Surface Warfare Center, Carderock Division – West Bethesda, MD

FY 2002 FUNDS: $433K

DESCRIPTION: Vessels of the Department of Defense (DoD) require unlimited access to national and international waters in order to successfully execute the government's defense and foreign policies. In order to enjoy such access, DoD vessels must be compliant with existing and developing environmental regulations pertaining to invasive aquatic species.

In order to develop a better understanding of the role DoD operations may play in the introduction of invasive aquatic species, ballast tanks of various classes of Navy and Army vessels will be sampled at two Naval Stations (i.e., Norfolk, and San Diego), and an Army Installation (i.e., Fort Eustis). The sampling plan concentrates on the size fraction of planktonic organisms for which invasions are well documented. Samples will be taken with a plankton net and preserved upon collection for enumeration at a later date. The physical and chemical characteristics of the ballast water will also be determined. Data will be obtained on the volume, loading location and management of ballast on board. The concentration of organisms and diversity of the ballast tank communities will be related to the characteristics of the ballast water, loading location, management practices, type of vessel, and date of sampling. Vessels will be sampled for spatial extent of fouling and species richness. Hull fouling communities will be sampled using a remotely-operated vehicle. Divers will collect hull samples to estimate species richness in the fouling community, and to identify any invasive species. Analysis of maintenance practices, including coating type, will be conducted for Navy vessels using the hull inspection database maintained.

BENEFIT: Data to determine if and how discharges from DoD vessels contain aquatic invasive species, and how these vessels should be managed will be the immediate outcome of this project. This effort will lead to the development of cost-effective, environmentally-compliant treatment and monitoring technologies or management strategies, designed to control the spread of invasive organisms, and meet the unique operating requirements of DoD vessels without jeopardizing operations or ship safety. This project is coordinating these research efforts with CP-1244.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: Results from the proposed research will support the activities of the Unified National Discharge Standards (UNDS) program. This program, managed jointly by DOD and the Environmental Protection Agency, is intended to analyze discharges from DOD vessels, and develop performance standards for pollution control devices that may be employed to treat these discharges. Non-indigenous species have been identified as a constituent of concern for several of the discharges examined. The data we obtain will guide the formulation of scientifically-defensible treatment standards under the UNDS program, and the development of effective pollution control devices, by providing information on the abundance and types of organisms found in ballast water and as fouling on hulls.

PROJECT SUMMARY

PROJECT TITLE & ID: Temporal and Modal Characterization of DoD Source Air Toxic Emission Factors; CP-1247

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Brian Gullett; U.S. Environmental Protection Agency – Research Triangle Park, NC

FY 2002 FUNDS: $555K

DESCRIPTION: Air toxic emission factor data are lacking, in part, due to the inability of current methods to address pollutant- and source-specific sampling and analytical challenges. This is particularly true for any kind of emission factors that adequately reflect the use mode and temporal nature of air toxics.

This project will develop an integrated methodology for measurement of trace organic and metallic air toxics using modified conventional measurements, state of the art laser-based technologies, and optical path monitoring in order to develop and test a sensitive, time-resolved methodology for detection of trace toxics that can be applied to mobile and stationary sources. This combination of three measurements methods (laser-based, conventional, optical path) provides a triangle of overlapping, confirmatory analyses that cover the broad range of organic and metallic air toxics. The project approach will be to combine three supportive measurement technologies into a method for assessing multiple source type air toxic emission factors under use-mode- and temporally- relevant conditions. Because the technologies have overlaps in terms of pollutant types, temporal spans, and modal relevance, this project can develop pollutant-to-pollutant correlations. The measurements rely on a combination of two time-resolved measurement technologies. Jet-REMPI and LIBS use a common seed laser source (Nd:YAG), providing an integrated, common platform for detection of most organic and metallic air toxics.

BENEFIT: Data from these efforts will be used to determine source- and mode-specific emission factors for use in the Air Force's Air Permit Information Management System (APIMS), an emission inventory system currently used by Hill AFB and being adopted DoD-wide, as well as to improve EPA's AP42 emission factor system. DoD will benefit from understanding how its base operations contribute to levels of ambient air toxics, both from a standpoint of being able to minimize impacts of potential operating restrictions as well as understanding how to limit occupational exposures (so called "hot spots"). Source identification and emissions characterization, coupled by an understanding of how specific modes of source sampling lead to emissions, will provide DoD with an effective tool for emission impact minimization.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: This project's developed methods and technologies will be published through the peer review literature and promoted through establishment of a Project Advisory Council (PAC), comprised of persons that have unique experience in development and use of advanced monitoring instrumentation for air pollution emissions. The project will work with the EPA Emission Inventory Group and the Air Force APIMS program for incorporation at DoD user facilities. It is also the demonstrated record of the investigators to publish and present their research and development findings, leading to increased exposure and acceptance of these methods. The combined technical expertise, military involvement, and multi-office EPA involvement ensures that the project output will receive broad and accepted use.

PROJECT SUMMARY

PROJECT TITLE & ID: Application of MALDI-MS to Identification of Phytoplankton in Ballast Water; CP-1248 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Dana Woodruff; Pacific Northwest National Laboratory – Sequim, WA

FY 2002 FUNDS: $100K

DESCRIPTION: Non-indigenous species are increasingly conspicuous in marine and estuarine environments throughout the world as invasions linked to ballast water transport. Innovative methods are needed to quickly and accurately identify the presence of and speciate non-indigenous and/or harmful phytoplankton in ballast water. Recent advances in ionization techniques such as matrix-assisted laser desorption/ionization mass spectrometry (MALDI-MS) have allowed detection of intact biomolecules within ballast samples. This project aims to develop and demonstrate the use of MALDI-MS for detecting and monitoring non-indigenous phytoplankton species in ballast water.

The first step will involve modifying MALDI-MS bacterial identification techniques currently being developed at Pacific Northwest National Laboratory (PNNL) for phytoplankton analysis. Using a pure strain of a representative phytoplankton species, an appropriate MALDI matrix material will be determined that is compatible with the analyte sample. Mass spectral "fingerprints" of this species will be examined for reproducibility using statistically-based algorithms. "Fingerprints" of several representative diatoms and dinoflagellates will then be developed. The second step will evaluate the reliability of MALDI-MS to identify the target phytoplankton species in ballast water of Navy vessels. Ballast water will be spiked with the target phytoplankton and analyzed using MALDI-MS. The high salinity of the sample medium and the biological complexity of the sample will be the technical challenges to address.

BENEFIT: The development of MALDI-MS for detecting and monitoring non-indigenous phytoplankton in ballast water will provide a streamlined, cost-effective approach to assessment and management of microorganism transport in ballast water.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: Potential follow on studies after the "proof-of-principle" phase would include: (1) Additional testing of environmental and ballast water samples from other geographic regions; (2) Expansion of the MALDI-MS spectral library with other representative phytoplankton species from other geographic regions worldwide; (3) Combining the phytoplankton MALDI-MS library to the existing MALDI-MS library of bacterial species; (4) Refinement of sampling and preparation techniques for automated sample extraction/concentration from complex environments; and (5) Application to other marine species including zooplankton, pahtogenic bacteria and viruses, and examination of increasingly complex mixtures.

PROJECT SUMMARY

PROJECT TITLE & ID: Adaptive Grid Modeling and Direct Sensitivity Analysis for Predicting the Air Quality Impacts of DOD Activities; CP-1249 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mehmet Talat Odman; Georgia Institute of Technology – Atlanta, GA

FY 2002 FUNDS: $100K

DESCRIPTION: Air pollutants emitted from DoD facilities may directly interfere with military activities such as training exercises, or in some cases even threaten life and property. Through long-range transport and transformation processes, these emissions may contribute to regional air-quality problems. Air quality simulation models are needed that can help determine the air quality impacts of various types of emissions from military installations. The primary objective of this project is to bring current air quality models to a level where they can be used to predict the impact on the surrounding environment of air pollutants emitted from military installations. The project will try to improve the models' ability to capture source-receptor relationships between emissions at local scales and air quality at regional scale by using prescribed burning emissions from Fort Benning as a case study.

The project will incorporate adaptive grid modeling and direct sensitivity analysis techniques that have been recently developed into one of the current air quality models (CMAQ or MAQSIP). While adaptive grid modeling will improve the air quality model by filling the gaps between local to regional scales, the direct sensitivity analysis will allow discerning the impacts of specific sources from cumulative effects on regional air quality. Simulations will be conducted to determine the air quality impacts of the prescribed burning operation at Fort Benning. In particular, the project team will try to estimate the sensitivity of ozone levels in the Columbus metropolitan area to NO_x and VOC emissions from the fires. Title V Air Emissions Inventory, which includes emissions of criteria pollutants (CO, NO_x, PM and VOC) by source, type and quantity, will be used. For the prescribed burning operation, the inventory is detailed enough to yield emission factors by litter type per acres burnt. These emissions will be processed for use with the CB-4 chemical mechanism. Simulation of a historic episode will enable a comparison of model results with observed air quality to determine if the modeling system is functioning properly.

BENEFIT: The techniques that will be tested are applicable to other military operations. Other types of emissions could be targeted, for example, from aviation, ship, or coastal operations at various locations. Once the concept is proven, the techniques can be used for the general purpose of predicting the fate of air pollutant emissions from various military sources. Products can be developed that can assist site managers in responding to immediate needs, as well as being able to plan future emissions that will minimize the impact on the environment.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The development of the proposed impact analysis approach has many upside potentials. The techniques will be implemented in the current generation of air quality models that are already in public domain. User training for these models is available for a nominal fee. Software and hardware requirements are not envisioned to entail any significant cost. Application of the model to other DoD operations may require further research. If the concept can be proven in this project, development of a user-friendly product tailored to DoD needs, along with a detailed plan for the transfer of this technology to DoD facilities may be addressed in a follow-on project.

PROJECT SUMMARY

PROJECT TITLE & ID: Developing Molecular Methods to Identify and Quantify Ballast Water Organisms: A Test Case with Cnidarians; CP-1251 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Brian Kreiser; University of Southern Mississippi – Hattiesburg, MS

FY 2002 FUNDS: $73K

DESCRIPTION: The objective of this exploratory research is to describe molecular markers and refine the methods necessary to identify cnidarian taxa in ballast water samples. The need for this work is based on the difficult and time-consuming task of using morphology alone to identify ballast water organisms. Furthermore, full identification of certain taxa is not always possible, leading to an underestimate of the diversity of organisms present. All the molecular methods to be employed are standard techniques. The novel aspect of this work that will require experimentation and optimization is developing protocols that apply these techniques to detect, identify and quantify ballast water organisms.

The basic protocol that will be developed in this project can be briefly summarized in four steps. First, the bulk DNA (from all the organisms present) is extracted from a sample. The polymerase chain reaction (PCR) is used to amplify a specific target gene from a specific group of organisms (cnidarians in this case). The PCR products are then cloned as a means of isolating the contributions of each species present. Finally, identifications are made by screening these cloned PCR products using a variety of techniques including size variation, restriction fragment length polymorphisms (RFLPs) and selective amplification by PCR. The development of the molecular protocol will be conducted in three phases. The first phase is to characterize the markers needed to identify various cnidarian species. This will involve determining which genes in the genome will provide the appropriate level of taxonomic resolution. The second phase will be to conduct lab tests of the marker's ability to detect the presence of specific cnidarian taxa at a variety of concentrations in mixed samples. As a "proof-of-principle" project, the bulk of the effort will be expended on the first two goals involving the development and laboratory evaluation of the techniques. However, in the third phase the technique will be tested on actual ballast water samples.

BENEFIT: Successful completion of the work outlined in this project will provide a powerful and versatile protocol that will be available to any worker with basic skills in molecular biology. One area that will warrant investigation is the use of the identifications derived from this protocol as a means of determining if ballast water exchange has taken place.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: Full implementation of this protocol will require several additional steps that will be straightforward to pursue once the initial methodology has been refined. A full characterization of all cnidarian species that may be present in ballast water is beyond the scope of this project. However, the only thing required for a complete taxonomic coverage is to acquire voucher material from around the world, particularly from ports visited by DoD vessels. This will allow workers to fully characterize the assemblage of cnidarians that may end up in ballast water. Of course, cnidarians represent only a fraction of the organisms present in ballast water as crustaceans, annelids and mollusks are by far more numerous. The power of this protocol is that it is versatile enough to be adapted to any taxonomic group.

PROJECT SUMMARY

PROJECT TITLE & ID: Automated Image Processing/Image Understanding Coupled with Artificial Neural Network Classifier for Detection of Non-Indigenous Species on Ship Hulls; CP-1252 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Stephen Lieberman; Space and Naval Warfare Systems Center – San Diego, CA

FY 2002 FUNDS: $100K

DESCRIPTION: Invasive (or non-native) species (NIS) have been introduced inadvertently into many marine and fresh waters via ship movements. Major transport pathways that have been identified include ballast water, tank sediments and ship hull fouling. To date, most information on invasive species hull fouling organisms is based on diver inspections of hulls which is costly, potentially dangerous, and often subjective.

The project team will evaluate the feasibility of developing automated image processing and understanding algorithms coupled with an artificial neural network classification scheme for quantitative measurement of the abundance and diversity of hull fouling organisms and to detect and classify NIS. The proposed automated quantification and classification system for complex shapes such as fouling organisms will make use of four processing modules: (1) image acquisition, (2) image pre-processing, (3) feature extraction, and (4) object classification. Estimates of fouling organism abundance (quantitative spatial coverage) will be derived from the digital images using image pre-processing and feature extraction techniques. Fouling organisms can be discriminated from unfouled hull based on differences in selected characteristics. In order to identify which fouling species are potentially invasive species, extracted characteristic features will be used to perform object identification and classification. The feasibility of developing artificial neural networks to automatically classify various types of fouling organisms isolated via the digital image processing procedures described above will be evaluated.

BENEFIT: The capability developed as a result of this effort it could be adapted to the Remotely Operated Vehicle (ROV) for Underwater Hull Evaluation that is currently under development at the Naval Surface Warfare Center (NSWC) Carderock Division. By combining high-speed digital image processing with the in-situ imaging and 3-D positioning capability provided by the ROV a methodology would emerge for rapid assessment of fouling organisms on ship hulls. This would represent a significant improvement over the current practice that relies on diver inspections and/or manual review of videos. The current practice of using divers for hull inspections is slow, costly, and often hazardous, and can be limited by environmental conditions. An automated system for evaluating hull fouling would also be useful for evaluating the effectiveness and condition of different hull coatings and for quick evaluation of hull condition to access ship readiness for operations.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The image processing/image understanding algorithms developed here could be transitioned to NSWC Carderock to enhance the capability of the Remotely Operated Vehicles (ROV) for Underwater Hull Evaluation currently under development. Although not part of the current ROV system, the technology could also be applied to images collected with a fiber optic based imaging system that could be used to inspect areas that are not normally accessible to routine inspections such as sea chests and associated piping systems.

PROJECT SUMMARY

PROJECT TITLE & ID: Development and Validation of a Predictive Model to Assess the Impact of Coastal Operations of Coastal Operations on Urban Scale Air Quality; CP-1253

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Alan Gertler; Desert Research Institute – Reno, NV

FY 2002 FUNDS: $303K

DESCRIPTION: Many east and west coast U.S. urban areas, classified as non-attainment for ambient air pollutants, are home to major DoD facilities. DoD operations can be significant sources of air pollutants and their precursors. However, there is considerable uncertainty associated with emission inventories of these coastal areas.

This project aims to develop and validate a prognostic modeling system capable of assessing the impact of coastal DoD operations on air quality. Included in this objective are the determination of primary and secondary pollutant concentrations, as well as their spatial and temporal variation. The goal is to develop a tool that helps in the design and implementation of effective strategies to reduce the impact of DoD operations on air quality in coastal urban areas. This project uses a method that links state-of-the-art meteorological, transport, and chemical modules by coupling a Lagrangian random particle dispersion model with an Eulerian chemical model. The impact of emissions inventory and meteorological parameter uncertainty on the model predictions are estimated. The model system is validated using real-world data obtained from a series of aircraft measurements performed in the San Diego area.

BENEFIT: The result of this study will enable DoD to: (1) Predict the impact and influence of coastal DoD facilities on urban and regional air quality; (2) Assess the contribution from individual sources to primary pollutant (directly emitted from sources) and secondary pollutant (formed by chemical reactions in the atmosphere) levels; (3) Estimate the impact of new technologies, fuels, and activity patterns on air quality; and (4) Design effective abatement strategies for primary pollutants and secondary pollutant precursors.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The model will be transferred to San Diego area military installation environmental personnel for application and to other coastal areas. The approach will be communicated and the model possibly transferred to other potential users.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmental Fate and Transport of a New Energetic Material, CL-20; CP-1254

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Roman Kuperman; GEO-CENTERS, Inc. – Aberdeen Proving Ground, MD

FY 2002 FUNDS: $442K

DESCRIPTION: The primary objectives of this research are to: (1) Determine transport and fate of CL-20 using standardized intact soil-core microcosm system; (2) Quantify the toxicity of CL-20 to soil invertebrates and plants in soil supporting high chemical bioavailability, and to aquatic biota; and (3) Examine the effect of a simulated weathering/aging process on CL-20 toxicity. The research will be conducted in two phases. In phase one, the toxicity of CL-20 to soil invertebrates, terrestrial plants, and aquatic species will be quantified. Both range-finding and definitive toxicity tests will utilize internationally acceptable standardized methods. This will include spiking of a natural soil, for which the major physical/chemical characteristics were determined, with a range of concentrations of CL-20. A portion of spiked soil will be subjected to a simulated weathering/aging process prior to bioassays. The bioavailable/labile fraction of chemical, in addition to total concentration, will be determined to assess chemical exposure. Aquatic assays will be conducted with both soil elutriates and directly amended water. The range of CL-20 concentrations tested will provide a continuum of exposure concentrations from "no effect" to "bioaccumulation levels" to "lethal levels," ensuring investigation of biological and chemical relationships across orders of magnitude in exposure concentration.

In phase two, transport and fate of CL-20 using standardized intact soil core microcosms will be characterized. Concentration levels will be determined from the results of the definitive toxicity tests conducted in phase one, and will include at least one safety factor of five above the EC50 level. Transport and fate will be assessed in the soil layers, plant and invertebrate materials, and leachates throughout the study period. Aquatic toxicity assays will be conducted with leachates to supplement information on potential toxicity of CL-20 in groundwater following transport through the vadose zone. This project along with CP-1255 and CP-1256 will develop collaborated methods for CL-20 analysis.

BENEFIT: The results from these studies will provide potential cost savings to both the risk assessment and remediation processes. In the past, chemicals similar in nature to CL-20 were released into the environment without knowing the fate and effects of these compounds. Millions of dollars and thousands of man-hours have been spent on risk assessment and remediation of previously released energetic compounds. By determining the chemical and physical fate of CL-20, as well as toxicological thresholds in aquatic and terrestrial environments, production, training, and disposal operations may be designed to avoid sensitive soils or ecosystems.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: This research project was designed to generate toxicity data for CL-20 that can be used directly for the development of screening levels according to the draft "Ecological Soil Screening Level Guidance" (US EPA) and protective benchmarks for aquatic species. The data transition to US EPA will be facilitated because project personnel are associated with the Eco-SSL National Task Group for developing Soil Invertebrate and Plant Eco-SSLs. Information developed in this project will be provided for munitions managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Factors Effecting the Fate and Transport of CL-20 in the Vadose Zone and Groundwater; CP-1255

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Szecsody; Pacific Northwest National Laboratory – Richland, WA

FY 2002 FUNDS: $342K

DESCRIPTION: Hexanitrohexaazaisowurtzitane (CL-20 or HNIW) is a promising replacement for existing propellants and explosives, since it releases more energy on ignition and is more stable to accidental detonation than energetic materials that now are being currently used. Wastes associated with DoD energetic materials constitute a major fraction of the Department of Defense (DoD) hazardous waste inventory. Therefore, it is critical that DoD consider the environmental fate and reactivity of CL-20 in sediments and in groundwater before it is replaced with currently used energetic materials.

The objective of this project is to characterize the fate and transport of CL-20 in subsurface sediments by focusing on the identification and quantification of geochemical and microbial reactions of CL-20 in sediments, the effects of weathering, and the influence of transport on these reactions in the subsurface environment.

Geochemical and microbial reactions, coupled effects, and effects of sediment weathering and flow are investigated using simple (e.g., uncoupled batch experiments) to more complex systems that represent field-scale transport (e.g., 1-D unsaturated/saturated transport, coupled reactions in natural sediments). Geochemical reactivity in batch systems are used to quantify sorption mass, rate, and reversibility, and the abiotic degradation pathway and rates. Anaerobic biodegradation of CL-20 and coupled geochemical microbial reactions and effects of aging are investigated. Individual and coupled reactions during unsaturated and saturated transport are quantified. A mechanism-based reactive transport model is used to predict CL-20 fate for a range of theoretical scenarios of CL-20 releases into the subsurface environment. This project along with CP-1254 and CP-1256 will develop collaborated methods for CL-20 analysis.

BENEFIT: By characterizing the fate and transport of CL-20 in the subsurface, the DoD has the ability to determine the appropriateness of CL-20 as a replacement for currently used propellants and explosives that are known to contribute to DoD hazardous waste inventory.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: Information from the results of this proposed work will be disseminated to the scientific community through peer-review publications. There will be an interlaboratory comparison of data to assess risk to the environment relative to other energetic compounds. Results of this proposed work, along with other CL-20 projects, will additionally be disseminated to DoD program managers through briefs and workshops for the purpose of providing information of CL-20 impact in the environment.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmental Fate and Transport of a New Energetic Material, CL-20; CP-1256

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jalal Hawari; Biotechnology Research Institute, NRC – Montreal, Quebec, Canada

FY 2002 FUNDS: $260K

DESCRIPTION: CL-20 is currently under consideration for a wider military application by the DoD. However, previous practices with similar nitramine explosives such as RDX and HMX have resulted in soil and groundwater contamination. Likewise, future activities with CL-20 might lead to similar environmental problems. CL-20 is relatively new and little data (e.g., physicochemical, biochemical and ecotoxicological) are available, making it difficult to predict its fate and impact in the environment. CL-20 is a heterocyclic nitramine, which like RDX and HMX, contains the N-NO_2 functional groups that characterize the explosives chemical and microbial properties. It has been reported that the characteristic bond cleavage of N-NO_2 in both RDX and HMX also occurs in CL-20.

This projects aims to (1) develop analytical methods to measure CL-20 and its degradation products in soil/water systems, (2) determine certain physicochemical parameters, and (3) conduct a series of ecotoxicological tests to collect preliminary data on the effects of CL-20 on selected ecological receptors. A multidisciplinary approach is employed by integrating chemistry, microbiology and ecotoxicology to determine the transformation/transport mechanisms and environmental effects of CL-20. An extraction method will be developed and validated through analysis of CL-20 and its degradation products in soil/water systems. It is the physicochemical parameters (K_{ow}, K_h, K_{oc}, K_d and S_{water}) that are essential for predicting its environmental fate and impact will be determined. Relevant abiotic and biotic degradability of CL-20 under aerobic and anaerobic conditions will be determined to understand its transformation processes. Standardized bioassays will be conducted to collect preliminary data on the toxicity of CL-20 to selected aquatic, terrestrial and avian species. This project along with CP-1254 and CP-1255 will develop collaborated methods for CL-20 analysis.

BENEFIT: Scientifically sound and convincing environmental data (transport, transformation and ecotoxicological effects) generated on CL-20 from this project will provide military personnel and other site managers with a knowledge base to help understand and predict the fate and environmental impact of CL-20.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The knowledge of (bio)degradability and ectoxicity of CL-20 generated from the laboratory work will allow the prediction of its environmental fate and effects in the field. This information can be used by the DoD to help make implementation or deployment decisions on CL-20. If CL-20 is adopted, this information can also be used by site managers and engineers to help design their remediation plans at contaminated sites. Besides, successful laboratory bench-scale microcosms for the degradation of CL-20 can provide the fundamental data for pilot-scale demonstration work and for optimizing the engineering parameters for field applications.

APPENDIX C
Conservation Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Assessment of Training Noise Impacts on the Red-Cockaded Woodpecker; CS-1083

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Larry Pater; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2001 COMPLETED PROJECT

DESCRIPTION: This project addressed the impact of training noises on the endangered red-cockaded woodpecker (RCW), and developed cost-effective techniques to evaluate and monitor effects of military noise on animal species. These techniques include the capability to characterize noise stimuli, document physiological and behavioral responses, and determine resulting population effects due to military noise. The approach assumed that proximate effects can be linked to individual fitness, which in turn can be linked to population effects. The proximate response was measured by observing the number of bird, flushing from the nest cavity and feeding behavior (non-nesting). Field studies of the in-situ response of the animal to the measured noise events were used to determine dose-response relationships. Individual fitness measurements included: number of young fledged per nest, adult turnover, group size, and mating success. These demographic parameters were correlated with measured noise levels. Another noise assessment considered involves correlating historic demographic data with estimated noise levels, using available training noise models. Four noise types were considered: artillery noise, small arms noise, helicopter noise, and maneuver noise. (i.e., combination of artillery, small arms, and helicopters.)

BENEFIT: This research will provide information required to assess and manage risk to military training capability, the endangered RCW, and other threatened and endangered species (TES). This project will also provide a basis for mitigation and management protocols and guidelines. This will help to alleviate impacts on training capability, avoid the need to acquire additional training land, and minimize litigation and delays.

ACCOMPLISHMENTS: During FY01, data reduction and analysis of the RCW noise dose-response data were completed, and baseline biological data were being analyzed and prepared for publication. These efforts involved the analysis of three years of field data. Dose-response relationships were established between noise level and the probability of proximate RCW response behavior and reproductive success. The project's findings show that the RCW successfully acclimates to military noise events. Additionally, the noise exposure did not result in any mortality or statistically detectable changes in reproductive success. An article about the project was published in the SERDP summer newsletter and several presentations about the project were made during the past year.

TRANSITION: The empirical data from these efforts will be integrated into leveraged RCW population models to assess noise impacts at the population level. Research results will transition into existing land management decision support tools (e.g., management guidelines for testing and training, and the first audiogram for RCW). Additionally, the results will direct the development of management protocols designed to minimize the impacts to endangered species population from noise generated by military activity.

PROJECT SUMMARY

PROJECT TITLE & ID: Error and Uncertainty Analysis for Ecological Modeling and Simulation; CS-1096

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Gertner; University of Illinois – Champaign, IL

FY 2001 COMPLETED PROJECT

DESCRIPTION: Although progress has been made in the areas of uncertainty analysis and error budgets, there is a need to develop the statistical and computational tools to enable model users to jointly assess and quantify the sources and magnitude of errors. These errors are associated with large-scale DoD simulation models used for resource assessment and management. The objective is to develop the methodology for formulating error budgets for environmental monitoring-modeling systems. This project provided the rationale to account for the effect of different sources of error on the uncertainty of model predictions, and for efficiently reducing that uncertainty. Modeling error was examined for the Terrain Modeling and Soil Erosion Simulation module of ATTACC and the spatical/distribution of disturbance model due to military activities.

The approach was to develop an analytical framework and a user-friendly interactive software package to assess and exert control over the quality of the simulation results. This project applies this methodology to a monitoring-modeling system [i.e., Army Training and Testing Area Carrying Capacity (ATTACC)] employed by the military for assessment and/or management of natural and cultural resources. The ATTACC model uses a spatially explicit version of the Revised Universal Soil Loss Equation (RUSLE). The RUSLE consists of six factors: rainfall-runoff erosivity factor and climate R, soil erodibility factor K, slope length factor L, slope steepness factor S, cover management factor C, and support practice factor P. The project developed a GIS-based methodology to make spatial and temporal predictions, analyze uncertainty, and build error budgets of soil erosion status based on and applied to military training

BENEFIT: This project will aid DoD's need to develop a comprehensive framework for quantifying, analyzing and managing uncertainty of modeling and simulation results. Additionally, the project will support general ecological and environmental modeling efforts in the other services.

ACCOMPLISHMENTS: In FY01, this project completed work related to uncertainty in remote sense imagery and implemented some of their uncertainty methodology in LMS and OO-IDLAMS. Much time was spent on the uncertainty software completion, including Level 1 to Level 3 software with documentation. All software will be accessible via the WEB. Three versions are available: (a) ATTACC specific (very user friendly); (b) General military models assessment; and (c) Academic version. The team met at North Arizona University with two other SERDP project groups (CS-1097 and CS-1100) and discussed their SERDP work and possible joint initiatives. This project presented papers at conferences and published many articles concerning uncertainty analysis over the year.

TRANSITION: This capability will provide the necessary quality control/assurance mechanisms to support DoD decision support systems regarding natural and cultural resources. This methodology will be relevant to all users of ecological and environmental models. Specifically, the uncertainty software developed in the project will likely be incorporated into Land Management System (LMS). However, the project will support general ecological and environmental modeling efforts in the other services as well. This research team has also met with the OO-IDLAMS team discuss incorporation of their results into OO-IDLAMS.

PROJECT SUMMARY

PROJECT TITLE & ID: Ecological Modeling and Simulation Using Error and Uncertainty Analysis; CS-1097

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Anthony King; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2001 COMPLETED PROJECT

DESCRIPTION: Ecological models are often used in conjunction with a geographical information system (GIS). This project: (1) identified and evaluated methods for quantifying uncertainty in spatial data for ecological models; (2) incorporated Monte Carlo analysis into a framework for uncertainty and error analysis of spatial data in ecological models; and (3) tested and demonstrated the Monte Carlo framework and tools with a case study.

The general technical approach was to account for the sources and the effect of uncertainty in simulation modeling. The investigation complemented the error budget approach and is closely coordinated with SERDP project CS-1096. The Monte Carlo framework was designed as general and modular software to maximize the ease with which alternative ecological models can be incorporated. This approach facilitated application to different installations, ecological models, and applications.

BENEFIT: The methods and tools developed by this project will be directly applicable to ecological models used throughout Department of Defense (DoD) and Strategic Environmental Research and Develop Program (SERDP). Incorporation of these methods and tools into the land-use decision process as part of an overall error budget analysis and through land-management systems like Integrated Dynamic Landscape Analysis and Modeling System (IDLAMS) and Land Management System (LMS) will directly benefit the DoD conservation practices and the DoD land-use decision process. The general concepts, methods, and tools resulting from this project will also be available to conservation and land-use decisions on private and public lands managed by other agencies, wherever spatially explicit ecological models are used as part of the decision process.

ACCOMPLISHMENTS: In 2001, much of this project's work focused on technology transfer. Several papers were published in journals and presentations were given. The papers address the influence of variability in spatial pattern on model results and ecological processes. In addition the project began development of a paper looking at the impact of uncertainty in spatial data on the results of the PATCH model. Methods and computer codes developed by CS-1097 for spatial uncertainty analysis were transferred to Dr. George Gertner of SERDP project CS-1096 for integration in that projects error budget analysis. The project organized an October workshop on spatial uncertainty in environmental models held in Flagstaff, AZ that involved participants from SERDP projects CS-1096, CS-1097, and CS-1100. A workshop report was drafted; which included identification of future research needs in spatial uncertainty analysis. Results of a study at Fort Hood, TX of the Federally listed endangered golden-cheeked warbler were documented in the projects annual report to SERDP, and a journal publication describing that case study is being prepared. In addition, the project completed a literature review of issues surrounding temporal changes in spatial uncertainty, and the project investigated the application of it's methods of spatial uncertainty analysis to the Fort Hood Avian Simulator Model (FHASM).

TRANSITION: These methods and tools will be incorporated into land-use decision processes as part of an overall error budget analysis, and as part of land-management decision support systems such as the IDLAMS and LMS. The project has coordinated extensively with other SERDP projects (e.g., CS-1055, CS-1100, CS-1102) to apply the methods of spatial uncertainty analysis to their respective modeling activities.

PROJECT SUMMARY

PROJECT TITLE & ID: Emerging and Contemporary Technologies in Remote Sensing for Ecosystem Assessment and Change Detection on Military Reservations; CS-1098

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Randall Karalus; U.S. Army Corps of Engineers Engineer Research and Development Center, Topographic Engineering Center – Alexandria, VA

FY 2002 FUNDS: $173K

DESCRIPTION: Federal land managers need accurate and affordable ways to assess the health and availability of their training lands. This research is designed to develop techniques that relate ecological concepts of carrying capacity, vegetation dynamics, critical thresholds, habitat fragmentation, ecosystem response and recovery, and land degradation to the response of remotely sensed spectral indicators, and ultimately, to training and testing upon military installations. The objective is to apply spatial and temporal change detection methods over a range of geographic scales using contemporary and emerging remote sensing technologies and traditional field surveys to identify and monitor land degradation.

The approach for this project is essentially a composite of: (1) mapping the installation or selected components thereof; (2) correlating the fundamental attributes of disturbance, vegetative cover, and plant succession; (3) analyzing, retrospectively, the ecological history of each installation in relation to land use; and (4) assessing high resolution systems to identify the sensor attributes necessary to monitor changes in plant species composition along disturbance gradients and plant succession stages.

Two types of analyses will be conducted: retrospective analysis, and ecotone and degradation gradient analysis. The purpose is to consider ecosystems in terms of their temporal and spatial characteristics, respectively. The retrospective analysis is a combination of (1), (2), and (3) described above. Whereas, the ecotone and degradation analysis is a combination of (1), (2), and (4). Analyses will be conducted at three facilities: Camp Williams, Utah - Army National Guard; Fort Bliss, Texas - U.S. Army; and, Marine Corps Air Ground Combat Center (MCAGCC), Twentynine Palms, California. Each of these facilities represents three of the four types of desert ecosystems in the U.S.: the Intermountain Cold Desert, Chihuahuan Desert, and Mojave Desert.

BENEFIT: Installation managers will benefit from standard techniques for cost-effective environmental change detection and extrapolation of field data through the use of remotely sensed data. The capabilities produced by this research will significantly improve the accuracy and cost/time-effectiveness of data collection, monitoring, and modeling for military land management.

ACCOMPLISHMENTS: Data acquisition efforts during FY01 included: hyperspectral imagery acquired over MCAGCC, Camp Williams, and Fort Bliss, twelve sites flown at a resolution of 1 meter, and one site flown at 4 meters (the last at the request of the Fort Bliss Environmental Office). Data transfer, importation, and registration of IKONOS imagery were conducted. At MCAGCC, each of the multiple spatial resolutions of emerging imagery (0.2m KODAK, 0.6m CAMIS, 1.0m CAMIS, 1.0 m IKONOS Pan/Multispectral Merge, 2.0m CAMIS, and 4.0m IKONOS) has been classified using an unsupervised training and classification procedure to acquire a cover classification.

Multi-resolution classifications of the Fort Bliss data and their accuracy assessments were conducted. Vegetation classifications were completed for all of Camp Williams Kodak data. Classifications were interpreted as they were developed by comparing them to ground data obtained during field trips to the various transect sites. During the year, this project developed an automatic classification protocol for aerial imagery. It has been applied to low altitude imagery from Fort Bliss and is being tested on imagery from other military installations.

Cover estimates derived from different spatial and spectral resolution imagery were compared to assess to what extent cover estimates vary with spatial resolution. The image derived estimates of cover were also contrasted with in-situ measurements of cover derived from 2 different field sampling methodologies (fixed-radius plots and line intercept plots).

Methods were evaluated for scaling vegetative cover estimates from large scale (high spatial resolution) imagery to smaller scale (coarser resolution imagery). Statistical relationships between vegetation cover from the high resolution samples and image brightness derived from the lower resolution imagery were identified.

TRANSITION: The project will acquire an impressive, and to a large degree unprecedented, array of imagery data types for three military facilities (National Guard, U.S. Army, and U.S. Marine Corps). University of Nevada - Reno (UNR) constructed a web site (http://www.ag.unr.edu/serdp) to facilitate data transfer. The website will be integrated with University of Illinois at Urbana and Utah State University's websites this year. The data will provide a baseline against which installation managers can compare future inventories and interventions. This database will not only be available for the installation managers and their environmental staff, but will also be available for further research and adaptation by other research organizations. Deliverables include: models for change detection of land use on military reservations; methods for scale transitions; relationships between hierarchical scheme of spectral and spatial resolution to ecotone/biological thresholds/degradation; protocols for data extrapolation from remote sensing imagery; and a better understanding of ecosystem response and recovery in relation to disturbance (land use).

PROJECT SUMMARY

PROJECT TITLE & ID: Predicting the Effects of Ecosystem Fragmentation and Restoration: Management Models for Animal Populations; CS-1100

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Sisk; Northern Arizona University – Flagstaff, AZ

FY 2001 COMPLETED PROJECT

DESCRIPTION: This project proposed to develop species-specific models that predict the responses of mobile animal species in heterogeneous landscapes in response to DoD training and related activities. Modeling efforts were built on connections between life history characteristics and the responses of mobile animals to habitat fragmentation and restoration. Field research focused on parameterization of models and testing of model predictions. The primary foci are the ponderosa pine forests and riparian habitats on military lands. This project was a cooperative effort involving Northern Arizona University, Colorado State University, the Ponderosa Pine Ecosystem Restoration Project, the Semi-Arid Land Surface Atmosphere (SALSA) Project, Camp Navajo (U.S. Army and Arizona Army National Guard), and Ft. Huachuca (U.S. Army). Three areas of investigation were conducted: (1) acquisition of ecological field data on the responses of animals to habitat fragmentation; (2) the mapping of animal habitats in three dimensions and at scales relevant to habitat management; and (3) the linking of empirical ecological data and spatially explicit habitat information in a management-oriented effective area model (EAM). Habitat mapping will rely on remotely-sensed data and field measurements. Land Remote-Sensing Satellite (LANDSAT) imagery and aerial photography permitted delineation of the spatial extent, shape, and juxtaposition of habitat patches. Important structural attributes were explored through the use of Synthetic Aperture Radar, aerial photography, and field measurements. Overlay of pertinent data sets in a Geographical Information System environment allowed integration of habitat attributes and identification of floristically and structurally distinct habitat types, as well as the edges that separate different habitat patches. Completed habitat maps served as input to the EAM.

BENEFIT: The project will link field and remotely sensed data in validated landscape models that will permit comparison of alternative land use strategies on wildlife species of management concern. The model operates in the ARC and ArcView geographic information system environments. Through manipulation of habitat maps, the EAM will be capable of predicting the effects of alternative landscape modifications -- habitat fragmentation due to operational activities, or habitat restoration resulting from rehabilitation or mitigation efforts -- on a wide range of animal species.

ACCOMPLISHMENTS: Field work for the purposes of understanding ecological relationships and parameterizing the Effective Area Model was completed. The structuring and coding of the EAM focused on refining capabilities presented in the beta-version, and on adding the ability to input nonlinear edge response functions. Significant theoretical effort focused on appropriate statistical approaches for modeling edge response functions. Spatial uncertainty assessment tools, developed by A. King et al., were applied which led to hosting a workshop on Spatial Uncertainty Analysis. During 2001 this project also produced and tested the "first generation" EAM predictions for forest and riparian ecosystems. This research team also pursued a greatly expanded outreach and technology transfer effort, oriented toward the military and civilian management community, as well as the ecological science and conservation audiences.

TRANSITION: The project results will be provided to land managers who will link field and remotely sensed data in validated landscape models that will permit comparison of alternative land use strategies on wildlife species of management concern. Extensive field testing of model predictions in different environments will permit evaluations of model effectiveness in forecasting the responses of a wide range of species to landscape-scale alterations in forested and riparian habitats.

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Units of Measure for Training and Testing Area Carrying Capacity Estimation; CS-1102

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Alan Anderson; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2002 FUNDS: $200K

DESCRIPTION: This project proposes to significantly improve the Army Training and Testing Area Carrying Capacity (ATTACC) methodology. The focus of this project is to develop quantitative units of measure to estimate training and testing land carrying capacity, extend the spatial and temporal scale of the methodology to include individual training areas and changes in training and land condition throughout the year, and validate the improved methodology. The enhancements that are being incorporated into the ATTACC model include: (1) revised water erosion model; (2) wind erosion model; (3) plant species composition; and (4) time varying climatic factors. The unit stream power approach for estimating the topographic factor of Revised Universal Soil Loss Equation (RUSLE) will be incorporated into the water erosion model to account for complex topography typical of military lands. Existing wind erosion models will be evaluated to determine which is the most applicable to military lands based on data requirements and model assumptions. The results from the completed SERDP project on Terrain Modeling and Soil Erosion (CS-752), are being used to improve estimates of land condition and can be extended to off-site impacts (sedimentation and water quality). To incorporate species composition into the ATTACC model, the Ecological Dynamics Simulation (EDYS) model will be utilized. A sub-model will be developed for the EDYS model that translates training/testing activities into changes in soil and vegetation processes. Existing DoD impact studies are used to estimate the primary impacts of military activities on soil and vegetation processes. Components of the ATTACC model will be modified to incorporate time varying climatic factors.

BENEFIT: By providing an improved methodology, mission impacts can more accurately be matched to the ecological capability of military lands to support those activities resulting in decreased land maintenance costs, maintaining realistic training conditions, and increasing land use capacities.

ACCOMPLISHMENTS: In 2001, this project selected appropriate units of measure for inclusion in the ATTACC model and developed a conceptual model for integrating multiple measures of land condition within the existing ATTACC methodology. This improvement was captured in ATTACC software that has been demonstrated to the ATTACC Implementation Team for evaluation. Improved water erosion models and species composition measures were incorporated into the ATTACC model. Field data were collected to parameterize and validate wind erosion model improvements to the ATTACC methodology. The research effort developed and demonstrated improved methodologies for estimating ATTACC Vehicle Severity Factor (VSF), Local Condition Factor (LCF), and Event Severity Factors (ESF). A framework for developing unit/event specific footprints based on training/testing doctrine was demonstrated. The framework involves several methodologies to account for varying levels of data to characterize mission activities. Studies were initiated to validate components of the ATTACC model against more detailed models and with historic data.

TRANSITION: Researchers are actively involved in the Army Corps of Engineers' Land Management System (LMS) initiative and are currently participating in the Fort Hood LMS Military Demonstration and activities of the LMS Integration Team. Project activities are coordinated with several DoD user groups including (1) the ATTACC Wind Erosion Advisory Group, (2) ITAM Installation Steering Committee, and (3) ATTACC Working Group. Team members have also been asked to serve on the United States Department of Agriculture (USDA) WEPS advisory group.

PROJECT SUMMARY

PROJECT TITLE & ID: Identify Resilient Plant Characteristics and Develop a Wear Resistant Plant Cultivar for Use on Military Training Lands; CS-1103

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Antonio Palazzo; U.S. Army Corps of Engineers Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory – Hanover, NH

FY 2002 FUNDS: $100K

DESCRIPTION: Wear-resistant plants are needed to mitigate environmental impacts and improve the use of Department of Defense (DoD) training lands. Knowledge of the relationships between military training and plant injury, regrowth, and wear resistance is limited. Plant and soil data will be combined allowing land users to make knowledgeable choices concerning plant selection and site-rehabilitation procedures to reduce soil erosion. This project intends to use several collections of resilient and other plants to breed new more resilient cultivars. A second objective is to conduct field and greenhouse studies to quantify the degree of compaction that occurs during training and relate soil condition to root injury in plants with known resilience.

The technical approach identifies and develops training-resilient plant cultivars. Field and greenhouse studies will be conducted to quantify the degree of soil compaction that occurs during training, relating this soil condition to root injury in plants with known resilience. The greenhouse study is on soil compaction and plant root growth. Three species are being studied (Reliant hard fescue, Blackwell switchgrass, and western wheatgrass) and three compaction levels in six soils. The field study is evaluating a naturalized cultivar and two native cultivars which were seeded in mixtures and in several different row-space combinations.

BENEFIT: This project will provide DoD guidance for mitigation methods in restoring training lands and will provide more resilient plant species that will help to increase training opportunities on existing training areas. This guidance will assist land managers and trainers in making choices on training schedules and in estimating cost and time requirements for maintaining military readiness.

ACCOMPLISHMENTS: During FY01, seed were harvested for SERDP select Syn-A Russian wildrye and a broad-based germplasm of slender wheatgrass originating from Fort Carson, Colorado. Fields were established for SERDP-select Sandberg bluegrass, western wheatgrass (2 populations), bluebunch wheatgrass, and western yarrow. Seed was harvested from SERDP-select Siberian wheatgrass and Snake River wheatgrass crossing blocks. Based on improved plant vigor, seed yield, and regrowth, clonal selections of Siberian wheatgrass and Snake River wheatgrass were polycrossed and the resulting seed was harvested.

Assessment of the recovery of soils from the tracking study at YTC continued. The early results indicate differences between species resilience to tracking maneuvers. Two years ago, 25 species received one treatment of 1, 2, or 4 passes. Those plots were evaluated by measuring percent target species, other species, weedy species, litter, and bare ground on and off the tracked area. Preliminary data suggests that, in most cases, the naturalized species were more resilient than the native species to vehicle tracking; however, western and Snake River wheatgrass showed promise as stabilization species.

TRANSITION: The results and findings of this project can be expanded to include the development and testing of additional plant species on a variety of soil types. This will provide opportunities for widespread application/demonstrations of this information to other testing and training ranges. This project will provide valuable information for organizations outside of DoD who deal with plant resiliency and soil compaction problems, as well.

PROJECT SUMMARY

PROJECT TITLE & ID: SERDP Ecosystem Management Program (SEMP); CS-1114

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Harold Balbach; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2002 FUNDS: $2631K

DESCRIPTION: The SERDP Environmental Monitoring Program (SEMP) was established as an outgrowth of the 1997 SERDP Management Scale Ecological Research Workshop during which it was determined that the DoD should establish a long-term ecological monitoring program at a military base with possible expansion to some other bases in the future. The overall program objective of SEMP is three-fold. First, SEMP directs and selects DoD relevant, ecosystem management research initiatives. Secondly, it manages a long-term ecological monitoring system(s) to support these research efforts while also fulfilling some of the host installations monitoring requirements. Finally, SEMP facilitates the integration of results and findings of research into DoD ecosystem management practices. The SEMP is managed by a separate Program Manager with the assistance of a Technical Advisory Committee (TAC).

Under the Ecosystem Characterization and Monitoring Initiative (ECMI), a team works with the host installation to gather, assess and document historic and current ecological data sources and monitoring efforts. In addition, this team is responsible for long term ecological monitoring. Data from the characterization effort, the monitoring efforts and the research teams all flows into the common data repository, shared by all research teams and the installation managers.

Selected research teams work in a collaborative context -- sharing field sites and approaches, entering data into a common repository, reviewing each other's findings, and contributing to common technology transfer mechanisms. Three research groups were initiated in FY99 to examine ecological indicators. The objectives are (1) to identify indicators of ecological change at multiple spatial and temporal scales, and (2) to establish relationships between ecological indicators and land use. In FY00, two research teams initiated the identification of ecological disturbance from military land use with the objective being to develop the knowledge to implement ecosystem management approaches for military lands.

BENEFIT: DoD's Conservation user community is directed to implement an ecosystem approach to land management issues. However, there is a critical need for scientific information to support this approach, especially as it relates to integrating ecosystem management with mission concerns. The success of user plans will depend on the capabilities and increased knowledge generated by research investment. SEMP will facilitate a number of studies that can be sufficiently planned and funded to allow a full array of remote sensing, ground truth experiments, modeling, cause-effect studies, etc. to be integrated to address complex problems. This contributes to data sharing, leveraging, and joint publications, supported by major experimental findings. Focused development of an ecosystem research plan, appropriate instrumentation and monitoring to support this research, and identification and selection of the most effective, technically sound research efforts to answer user needs will all contribute to the science and understanding necessary for an ecosystem approach to land management.

ACCOMPLISHMENTS: The SEMP program management accomplishments for FY01 include (1) an annual research coordination meeting with all of the research groups associated with Ft. Benning studies, (2) technical advisory meetings with the SEMP technical advisory committee, and (3) a technology transfer workshop in FY01.

The ECMI team completed the design and implementation phase as described in the Long-Term Monitoring Program. The surface water component was re-designed and re-implemented during summer 2001 to accommodate the current drought trend and subsequent low stream flows. The ground water monitoring system was fully implemented and data are being retrieved on a monthly basis and entered onto the SEMP data repository. A land cover map (using 1999 LandSAT TM data) and accuracy assessment was developed. The erosion/deposition and woody productivity components were fully implemented during FY01.

The SEMP data repository has been maintained, and reevaluated. The repository was determined to meet the specific requirements and guidelines set up for its original purpose. However, numerous recommendations to further enhance, expand, and improve the overall design and functionality of the repository were made.

Under the research project **Determination of Indicators of Ecological Change,** Dr. William DeBush, University of Florida, evaluating relationships among ecological indicators and land condition following soil and vegetation sampling of 300 sites over a broad area encompassing a range of military and non-military land use and anthropogenic disturbance (low-intensity sampling). From this analysis, a short list of promising indicators will be selected for further evaluation. Concurrently, a watershed scale evaluation of hydrologic response to intensive military land use has been ongoing in paired watersheds. Preliminary results have revealed a strong relationship between land disturbance and plant-available water (soil moisture) and nutrients. During the next year hydrologic, soil and vegetative indicators will be evaluated in localized areas of relatively homogeneous environmental conditions (high-intensity sampling) to determine short-range spatial and temporal variability in indicator response. Additional watershed-scale monitoring in four representative basins will be used to link hydrologic cycling with vegetation patterns and soil biogeochemical characteristics.

Under the research project **Development of Ecological Indicator Guilds for Land Management**, Dr. Anthony Krysih of Embry-Riddle University is investigating ten ecological indicator systems to assess and monitor landscape conditions and trends on the basis of ecologically relevant metrics and unbiased statistical methods. Nine study sites were selected at Fort Benning that represented three replicates each in low, medium, and high disturbance landscapes. Over 110,000 measurements of plant leaves have been made in the laboratory from field specimens collected in spring 2000 and 2001. Fluctuating Asymmetry associated with habitat disturbance gradients has been demonstrated in Winged Sumac (*Rhus copallina*) and Morning Glory (*Ipomoea pandurata*). Plant physiological responses also differed among the disturbance sites, suggesting that plants in highly disturbed habitats are exhibiting more ecological stress. Physiological parameters that were found to be significant include: transpiration rates, stomatal conductance, and variable fluorescence. Ants, spider and grasshopper species were investigated to determine if the species' occurrence (type and distribution) correlates to habitat disturbance. Important patterns were observed for soil microbial and chemical dynamics in soil. One-Way Analysis of Variance (ANOVA) using Bonferroni adjusted post-hoc multiple comparisons was used to assess the statistical significance of individual habitat parameters among the three levels of habitat disturbance (Low, Medium, High). Low and Medium sites were very similar to each other, while High sites were clearly different.

Under the research project **Indicators of Ecological Change,** Dr. Virginia Dale of Oak Ridge National Laboratory has completed several efforts and initiated others in FY01. The historical reconstruction of the 1827 forest types was prepared based on Land Office records. Field studies have determined the understory characteristics of sites with different training intensities, found that microbial biomass in the soil decreased with increasing levels of disturbance, examined macroinvertebrarte community structural changes as related to disturbance, and developed comparisons of stream sediment and dissolved mineral concentrations across a spectrum of disturbance and discharge regimes. This project's accomplishments have been highlighted in Section (Significant Accomplishments).

Under the research project **Disturbance of Soil Organic Matter and Nitrogen Dynamics: Implications for Soil and Water Quality**, Mr. C. Garten, Oak Ridge National Laboratory investigated the possibility of thresholds associated with natural and/or anthropogenic disturbance that establish the potential recovery of soil quality on disturbed lands. Preliminary soil sampling will be used to determine variability in measures of soil quality and to design more intensive pre-treatment soil sampling. An approach to determine the thresholds for soil quality based on simple mathematical models of soil C and N dynamics were initiated. The model calculates belowground and aboveground biomass as well as the C inputs to soil and potential excess N (i.e., available soil N). Simulations with the model indicate that there are various sets of conditions where soil C stocks become too low to achieve any recovery to a desired future state. As part of preliminary model development and an analysis of refractory soil C, an analysis of fire history data in training compartments at Fort Benning was undertaken.

Under the research project **Thresholds of Disturbance: Land Management Effects on Vegetation and Nitrogen Dynamics**, Dr. Beverly Collins, Savannah River Ecology Laboratory completed the baseline monitoring in FY00. In FY01, field monitoring equipment, protocols, and pilot studies were set in place to compare the environment, nitrogen dynamics, and vegetation among sites over the study period. To date, the available NH_4-N in the soil is highest on the low use-clayey sites while NO_3-N is highest on the heavy use-sandy sites. The higher NO_3 values on the heavy use-sandy sites suggest a potential for nitrogen losses in these sites following disturbance. The A horizon is deeper in the low use sites compared to the heavy use sites and the pooled O horizon mass is greatest on the low use-clayey sites.

TRANSITION: The goal of SEMP is to provide knowledge, tools, and techniques to contribute to understanding and enhancement of the ecological role of military installations within their ecoregions. Project results and findings will be integrated into DoD ecosystem management policy and procedures to provide DoD land managers the necessary guidance and tools for a sustaining future military training and testing. The monitoring and research results will also be available to other Federal land managers.

PROJECT SUMMARY

PROJECT TITLE & ID: Diagnostic Tools and Reclamation Technology for Mitigation Impacts of DoD/DOE Activities on Arid Areas; CS-1131

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. W. Kent Ostler; Bechtel Nevada – Las Vegas, NV

FY 2002 FUNDS: $519K

DESCRIPTION: This project is designed to overcome current gaps in diagnostic capabilities needed to distinguish between various degrees of sustainable and non-sustainable impacts due to military training and testing activities in desert ecosystems. Additionally, the project aims to develop and evaluate new and cost-effective techniques for rehabilitation and restoration of such disturbed habitats. For diagnostic techniques, new rapid detection methods will be developed using hand-held digital cameras and Hi-8 camcorders to record selected ground data. Combinations of innovative revegetation techniques developed at sites in the Mojave Desert will be applied to disturbed lands at Fort Irwin. The approach includes the establishment of plots of land representing 5 to 10 classes or degrees of disturbance ranging from light disturbance to very heavily disturbed sites (non-vegetated). Plots will be treated at Fort Irwin with revegetation techniques. Vegetation and site conditions will be documented in representative areas for each degree of disturbance. Ground data from the sites will be correlated with remote sensing data. Field data will be taken over a four-year period by the proposed image collection techniques previously described.

BENEFIT: Approximately 70% of all U.S. military training lands are located in arid areas that will benefit directly from these technologies. Under current technology, it is estimated that up to 35% of revegetation projects will fail. Applying the results of this project will increase the success of the restoration and possibly save DoD as much as $5 million annually. These diagnostic tools will enable management to maximize utilization of limited training environs and thus increase operational readiness.

ACCOMPLISHMENTS: During FY01, IKONOS data were acquired from the MCAGCC-29 Palms area to evaluate and expand the utility of the imagery. Software was developed to assist in automating the process of developing a spatial map of vegetation cover. The project completed a demonstration of the diagnostic software which included mapping of a large section of the southern part of Fort Irwin. This was provided to personnel at Fort Irwin who took that information and put it in their GIS system to obtain estimates of cover by training ranges. Prior to this research, Ft. Irwin had never been able to obtain this type of data. Data were obtained from helicopters of LCTA plots that were sampled in 2001 to validate accuracy of these techniques. Aerial photography from 1997 and 1999 were compared for an area at Fort Irwin to show degradation of the vegetation can be detected using techniques developed by this project. Fort Irwin personnel came to Las Vegas and were trained in the use of the techniques. Ft. Irwin has since used this software to map vegetative cover over the entire area at Fort Irwin. LIFI equipment was taken to Fort Irwin to detect if stress could be determined from damaged plants of several species. A second set of reclamation trials were established that have focused on pretreating seeds of the dominant species at Fort Irwin to enhance germination.

TRANSITION: Technologies developed by this program can be used for a variety of applications currently needed by government agencies with land management responsibilities in both arid and moist environments. The primary applications include: (1) evaluating and monitoring the site's ability to recover from various levels of impacts, (2) rapidly assessing shrub density, height, diameter, size class and percent canopy cover (important for controlling erosion), and (3) developing cost-effective revegetation techniques. Results from this project will be integrated into land management decision support tools to provide DoD land managers the necessary guidance for mitigation methods that will help to increase training opportunities on existing training areas.

PROJECT SUMMARY

PROJECT TITLE & ID: Application of Hyperspectral Techniques to Monitoring and Management of Invasive Weed Infestation; CS-1143

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Susan Ustin; University of California – Davis, CA

FY 2002 FUNDS: $403K

DESCRIPTION: The rapid spread of non-native invasive plant species, including noxious weeds is causing irreparable damage to the natural resources on military installations. This project aims to develop and demonstrate a new remote sensing methodology using hyperspectral imaging (HSI), for mapping invasive weeds. Seven bases have been selected that have different weed types, intensities, and patterns of environmental disturbances from the southeast, southwest, and northwest ecoregions of the U.S. to demonstrate, refine and validate the proposed methodology. These case studies will demonstrate the portability of the methods under conditions of different types of military activities. Wall-to-wall maps will not be developed. Instead, appropriate airborne flightlines that include a range of types of weed problems on the base, intensity of invasive weeds, and encompass a range of land use conditions will be identified. These data will provide a basis for demonstrating and assessing the benefits of HSI data for mapping various species of weeds under the diverse conditions existing at each of these military bases.

New support vector machine learning tools will be used to characterize the habitats and identify weeds in the HSI imagery. The Hierarchical Foreground Background Analysis (HFBA) is one example of a multi-scale resolution analysis that is used to link the spectral variation for each pixel with variation in the spatial domain. The HFBA decomposition is coupled with a wavelet-based, multi-scale resolution in the spatial domain. This method addresses three issues regarding spectral features which are not addressed by standard methods of image analysis that focus on each pixel separately. Spectral redundancy, the span and completeness of a supervised classification, and a mechanism for producing an automatic classification are the key issues to be addressed. The combination of HSI tools for analysis of field spectra and images will provide a robust protocol for monitoring ecosystems that can be applied, even when the specifics of the location and the nature of the invasive species changes. The tools will be compatible with existing Land Management System (LMS) environmental management models.

BENEFIT: The immediate benefit of this project will be a better understanding of the distribution of major invasive weeds on military bases and the environmental conditions associated with their distributions and spread. The long-term benefit will be in developing a cost-effective method for mapping weeds that can be used to monitor spread of weeds to new locations.

ACCOMPLISHMENTS: In FY01, evaluation of HSI weed maps at Vandenberg and Camp Pendleton were completed. The maps showed high accuracy of prediction for weeds in field tests. HSI overflights, field measurements of ecological characteristics and spectral characteristics of habitats and weeds were completed at Ft. Benning. AVIRIS image data from NASA was acquired over Camp Vandenberg. GIS databases from Yuma, Yakima, and Ft. Benning have been acquired and field data from the summer 2000 and 2001 was analyzed.

TRANSITION: Demonstrations of the tools will be provided to site personnel and written technology transfer documents and a web based training course as part of the technology transfer objectives will be developed. The image analysis and other software tools to be developed are compatible with GIS based management protocols and compatible with LMS software.

PROJECT SUMMARY

PROJECT TITLE & ID: Exotic Annual Grasses in Western Rangelands: Predicting Resistance and Resilience of Native Ecosystems Invasion; CS-1144

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jayne Belnap; U.S. Geological Survey, Canyonlands Field Station – Moab, UT

FY 2002 FUNDS: $276K

DESCRIPTION: This project is examining what controls whether a system is susceptible to invasive species. While physical disturbance appears to play a role, many disturbed areas are not invaded, while many undisturbed areas have been invaded. This project proposes to (1) determine if the current distribution of cheatgrass (*Bromus tectorum* - an invasive species) and other annual grasses can be predicted on a landscape and regional level using soil chemistry; (2) construct a model that predicts which soils are resistant or susceptible to annual grass invasion for a large watershed; (3) investigate positive feedback loops that may perpetuate annual grass dominance, such as altered soil organic matter, litter, or chemistry; and (4) examine ways to favor native plant re-invasion by altering soil chemistry.

The initial focus will be the random selection and sampling of sites. These sites will represent major habitat types (based on vegetation and soil types) within the watershed surrounding Virginia Park. At each site, slope, aspect, elevation, soil type, past and present anthropogenic disturbance and distance to roads will be noted. Cover of vascular and non-vascular vegetation will be estimated. Soil depth and stability will be assessed along with chemical properties. Soil food webs will be analyzed as well. Magnetic properties, which indicate the presence of windblown dust, will be measured. Regression analyses will be done to see what factors best predict the presence of *Bromus*. If nothing is found to predict cheatgrass presence, the above will be repeated in an area of winter-rain only.

BENEFIT: This project will aid installation managers in predicting what soils are susceptible to invasive species and facilitate re-establishment of lost habitat. In addition, understanding how annual grass invasion changes natural ecosystem processes, such as nutrient availability, water availability, and soil microbial systems and how these changes affect re-establishment of native perennial plants, will enhance efforts to restore lost habitat. Specifically, the information resulting from this project will help prevent *Bromus* invasion, and therefore, sustain valuable military training and testing lands.

ACCOMPLISHMENTS: All major soil/vegetation sites in SE Utah were surveyed for *Bromus* occurrence. Soils were collected and analyzed for macro and micronutrients at each site. Data on soil series, lithologic units and soil age were identified, and the cover of the dominant vascular vegetation was assessed. Preliminary analysis indicates that soil series is not a good indicator of *Bromus* occurrence, but that soil lithology and age is an excellent indicator. Monitoring continued on the 1995 *Bromus* invasion for effects on soil chemistry and vascular and non-vascular plants. The native perennial grass *Hilaria* is negatively affected by *Bromus*, but the perennial grass *Stipa* is not. Cover of phototrophic non-vascular species has not changed since the initial large response to the invasion. A wide range of soil amendments, at a wide range of concentrations, was applied to *Bromus* and *Hilaria* in the greenhouse. It was determined that 5 different amendments do not affect *Bromus* germination, but significantly reduce emergence, while not significantly reducing germination or emergence of the native grass *Hilaria*.

TRANSITION: The projects resulting from this project will include datasets, metadata, technical reports, scientific publications and field consultations with land managers. Printed and digital media will be distributed. The project results will have impact on directing the specific management actions relative to *Bromus* invasion.

PROJECT SUMMARY

PROJECT TITLE & ID: Integrated Control and Assessment of Knapweed and Cheatgrass on Department of Defense (DoD) Installations; CS-1145

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mark Paschke; Colorado State University – Fort Collins, CO

FY 2002 FUNDS: $417K

DESCRIPTION: The objective of the project is to develop a strategy for the control, monitoring and prediction of knapweed and cheatgrass infestations at two military installations in the Western U.S. The technical approach evaluates the combined effects of (1) biological control using insect pathogens, (2) fire, (3) manipulation of soil N availability, (4) seeding with native late-seral species, and (5) restoration of the soil community. A replicated partial factorial arrangement of test plots in established communities of cheatgrass and knapweed are being used. The results of these manipulations on plant community composition will be monitored over a four-year period in order to evaluate success. Results from our study will be incorporated into an existing ecological dynamics simulation (EDYS) model. The EDYS model will be calibrated to each of the field study sites to assess the direct and indirect effects of treatments on ecosystem dynamics at multiple spatial scales, and to project potential effects of treatments on long-term successional dynamics. Remote sensing methods will be used to test the effectiveness of these methods for monitoring population densities of weed species over a large area.

BENEFIT: This project will provide be a new effective methodology for controlling non-indigenous invasive plant species. The overall long-term benefit will be reduction of knapweed and cheatgrass populations on military installations and other lands, and a return of native plant communities to provide more realistic training areas and thus improve mission readiness.

ACCOMPLISHMENTS: A project web page (www.cnr.colostate.edu/RES/rel/serdp) has been established to facilitate communication between collaborators and to share project findings with the user community. First year (post-treatment) data were collected for each of the 160 research plots. These data include plant community biomass composition, soil fungal community assessment, soil nitrogen availability, and knapweed biocontrol population assessments. Populations of insect biological control agents released in 2000 have established during 2001. Density of knapweed plants, seedheads, and insect populations were quantified. Treatments to reduce soil nitrogen availability (sucrose amendments) have continued throughout 2001. The effectiveness of this treatment has been monitored throughout the growing season using in-situ ion-exchange resin (IER) bags. The DOE Remote Sensing Lab (RSL) completed remote sensing tasks of research plots at YTC. This included acquisition of 11 channel Daedalus 1268 multispectral scanner (MSS) data, acquisition of 32 channel Daedalus 1268 short wave infrared (SWIR) scanner data, geodetic rectification of both MSS and SWIR data, precise GPS surveying of plot corner markers, and acquisition of field spectra of the major plant species present. The Ecological Dynamics Simulation (EDYS) model has been implemented and calibrated for the test sites at the two military installations using both existing information and the plot-specific baseline data collected in 2000. The literature and first-year data have been used to calibrate a “first pass” model version.

TRANSITION: Resulting methodology for controlling these weeds will be made available to others by the means of peer-reviewed journal articles, web pages, and presentations at scientific meetings and symposia. The project results will directly serve to facilitate current management actions at military installations.

PROJECT SUMMARY

PROJECT TITLE & ID: Developing Biological Control of Garlic Mustard; CS-1146

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Bernd Blossey; Cornell University – Ithaca, NY

FY 2002 FUNDS: $162K

DESCRIPTION: Garlic mustard (*Alliaria petiolata*) is one of the most serious invasive species in the Eastern and Midwest United States replacing native spring wildflowers in forest communities. Physical, mechanical, and chemical means have failed to provide long-term control. The development of biological control appears the only viable option for ecologically sound management of garlic mustard. This project focuses on the development of a standardized long-term monitoring plan to assess the impact of released biocontrol agents on target plant and associated plant communities. Personnel at CABI Bioscience Center in Switzerland will undertake detailed investigations on the ecology, life history and impact of 5 potential biocontrol agents for garlic mustard native to Europe and determine their host specificity. An important focus of the investigations will be to observe changes in plant growth or biomass allocation of garlic mustard in response to different densities of control agents. In addition, the influence on plant performance as a result of attack by single or multiple species (i.e., on above and below ground plant tissues) will be assessed in the field and in common garden experiments. These studies of herbivore interactions will help determine whether the introduction of multiple agents is warranted or should be avoided.

To assess the impact of the release of biocontrol agents on garlic mustard and native plant communities, a standardized monitoring protocol will be developed. Potential field sites will be visited and long-term monitoring sites will be established. Data will be collected on garlic mustard performance and abundance at sites in North America and in Europe. Basic site specific parameters (exposure, overstory species, soil types etc.) will be recorded to evaluate the influence of habitat types on the control success.

BENEFIT: The development and implementation of biological weed control programs, e.g., the introduction of host specific herbivores from the native range of a non-indigenous plant species, offers an ecologically sound, cost-effective, long-term management strategy that will help protect native species and their habitats.

ACCOMPLISHMENTS: During the 2001 field season, host specificity tests at CABI in Switzerland were conducted using plants provided from North America and additional species available in Europe. The field activity periods of the selected 5 biological control agents makes host specificity screening an almost year round activity. During summer 2001 the testing with the two stem-mining weevils *Ceutorhynchus roberti* and *C. alliaria* were completed. Testing for the seed feeder *C. constrictus* and the root-feeding *C. scrobicollis* are well advanced. Tests for the stem-mining weevils and the host specificity testing for *C. constrictus* and *C. scrobicollis* was completed as well. Experiments investigating the impact of two stem-mining weevils and of the root-mining weevil on performance of garlic mustard have been completed. A protocol for monitoring the effect of insects after their potential release in North America has been field tested. As part of the long-term monitoring, the researchers asked managers to provide quantitative samples of garlic mustard stems from various regions. As a result, a database was established containing >4000 stems and will be able to make assessments of distribution and abundance of insects associated with garlic mustard in North America.

TRANSITION: This protocol will be used by researchers and natural resource managers at military installations and other agencies to monitor the success of control agents after their release in North America. Workshops and manuals will be used to introduce resource managers to the application of biological weed control and in the use of the monitoring protocol.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic Monitoring of Threatened and Endangered Species in Inaccessible Areas; CS-1185

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kurt Fristrup; Cornell University – Ithaca, NY

FY 2002 FUNDS: $232K

DESCRIPTION: Large parcels of known or suspected TES habitat are in areas that are inaccessible to ground personnel because of operational restrictions or unexploded ordnance. Because biologists are unable to use traditional ground-based survey methods in these areas, this project will develop an airborne monitoring system for taking censuses of acoustically active species from the air.

The monitoring system will consist of three components: (1) a microprocessor-controlled digital data recording system that can be deployed either on the ground or on an airborne platform; (2) a helium-filled lift vehicle that can carry the recording system aloft for drifting or tethered deployments; and (3) a software package for automatic extraction, identification, and localization of sounds of interest. All three components represent plausible extensions of technologies that have been successfully implemented by the Cornell Bioacoustics Research Program and its affiliates. The completed system will enable long-term or wide area acoustic monitoring, with fully automatic data reduction. Post-deployment processing will be capable of producing a map of sound source locations and a log of species and time of call for all detections of interest. Summary statistics regarding call density, the estimated density of animals, and measures of the uncertainty of these estimates will be produced. Fully functional systems will be provided to Fort Hood, Texas for surveys of golden-cheeked warbler (GCWA), black-capped vireo (BCVI), and Bell's vireo.

BENEFIT: This project will result in deployment of a fielded system that will enable natural resource managers at Fort Hood to obtain data on the presence and distribution of the endangered GCWA and BCVI within the 60,000-acre live fire area. Such data have previously been either sparse or non-existent because of access restrictions to this area. In the long term, application of the tools to be developed in this project should reduce the cost and operational impact of conducting biological surveys in areas where such surveys interfere with military operations. The resulting data will support the development and implementation of management plans to protect TES and their habitats while minimizing impacts on the military mission.

ACCOMPLISHMENTS: During 2001, focal animal and array recordings were obtained using shotgun microphones and a six element system that spanned 160 m x 30 m. Automatic digital recording systems were used to gather 40 days of data in BCVI habitat. Digital transcription of an extensive library of GCWA recordings was arranged. A tethered blimp system was developed and set up for testing over the array. A pitch extraction algorithm was developed to extract the frequency modulation characteristics of bird song and designed to run in real time. Distinctive features of GCWA songs have been identified, and some potentially distinctive song elements have been identified for BCVI. Acoustic localization using the array data indicates that GCWA and BCVI songs are regularly detected over 100 m from our microphones under favorable conditions. Examples of detection distances up to 200 m have been logged. Preliminary indications of the effects of cowbirds on singing activity have been recorded. These results, if confirmed, may prove important for understanding the dynamics of nest parasitism, and they indicate that monitoring cowbird vocal activity may prove important for accurate acoustic censuses.

TRANSITION: The equipment and methods to be developed in this project will be applicable to monitoring acoustically active TES that occur at other DoD installations, such as the red-cockaded woodpecker (Fort Bragg, Fort Benning, Fort Stewart), Mexican spotted owl (Fort Huachuca), and least Bell's vireo (Camp Pendleton).

PROJECT SUMMARY

PROJECT TITLE & ID: Riparian Ecosystem Management at Military Installations: Determination of Impacts and Restoration and Enhancement Strategies; CS-1186

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Patrick Mulholland; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2002 FUNDS: $385K

DESCRIPTION: Military activities can have negative impacts on riparian ecosystems. DoD recognizes the critical importance of riparian ecosystems as habitat and controls on adjacent aquatic ecosystems. To help DoD better balance land stewardship with its training missions, this project is designed to increase understanding of riparian functions and stresses, and the ecological effects of specific riparian restoration strategies. Two objectives will be addressed: (1) the identification of impacts of upland (erosion) and riparian disturbances (denudation, fire) on riparian functions; and (2) the evaluation of the effects of riparian restoration involving woody debris additions and revegetation to channels. Impacts of current stresses on riparian functions will be based on measurements and comparison of these measurements in catchments at Ft. Benning , GA. Both reference catchments and disturbed catchments that represent a range of disturbed conditions will be monitored and characterized. The degree of disturbance or disturbed condition of a catchment is determined by the percentage of denuded land. Riparian and stream characteristics and processes will be quantified in each catchment. Soil and vegetation measurements will be used to define riparian processes. Stream measurements include hydrologic, nutrient and sediment concentrations, metabolic, and periphyton and macroinvertebrate communities. The restoration phase of this project involves woody debris additions in ephemeral channels and 1st/2nd order streams of highly disturbed catchments. Revegetation, using native grasses and woody vegetation, will be conducted in highly disturbed ephemeral channels. The efficacy of the two riparian management restoration strategies (i.e., woody debris additions, and revegetation) to relieve stresses and improve riparian ecosystem functioning will be evaluated.

BENEFIT: The long-term benefit of this project is an increased understanding of riparian ecosystem functions, how military training activities can impact those functions, and how land management activities at military bases can be designed to reduce or eliminate these impacts. The results of this research will provide managers with the information needed to make better land management decisions and more effective restoration plans that can sustain military base ecosystems and the training missions they support.

ACCOMPLISHMENTS: Eleven study sites (3 reference, 8 disturbed) have been selected for both the riparian (vegetation and soils) and stream (hydrology, chemistry, biology) studies. The disturbed catchments include a range of disturbance intensities that should provide the gradient of disturbance levels over which impacts will be determined. Cursory vegetation surveys and reconnaissance of soil and topographic conditions have been completed for all potential ephemeral drainages. Based on this information, paired plots for vegetation and soil investigations have been delineated in approximately 80% of the drainages. These pairs consist of one plot placed within topographic positions deemed most susceptible to impact and another located where impacts are less commonly observed (i.e., in a less susceptible topographic position within the same drainage).

TRANSITION: This project will provide prioritized and simplified riparian assessment metrics and protocols which can be used to help facilitate the development of riparian restoration and adaptive management support tools for land managers and military trainers. Additionally, projects findings and data will be immediately useful and integrated into SERDP Ecosystem Management Project (SEMP) which is a long-term monitoring and research initiative at Ft. Benning, GA.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic Response and Detection of Marine Mammals Using an Advanced Digital Acoustic Recording Tag; CS-1188

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peter Tyack; Woods Hole Oceanographic Institute – Woods Hole, MA

FY 2002 FUNDS: $380K

DESCRIPTION: This project will quantify the probability of passive detection of marine mammals in Navy range waters which is currently hindered by an absence of information regarding the vocalization rate, level, and spectral characteristics for many marine mammals found in Navy range waters, especially deep-diving whales. The second objective is to evaluate the short- and long-term impacts of Defense activities on marine mammals. Woods Hole Oceanographic Institution (WHOI) has developed a miniature digital acoustic tag, the DTAG, that provides high fidelity, on-animal recordings of vocalizations and ambient sound. The tag also includes orientation and dive sensors, and provides a uniquely direct means for establishing the behavioral response of a whale to an impinging sound. This project will perform a series of field experiments combining surface observations with on-whale recordings using the DTAG. Focal follows of tagged animals will produce a database of vocalizations from whales with identified species and behavior. These data will be used to estimate vocalization rates. The second experiment involves simultaneous recordings of vocalizations at a tagged animal and at range hydrophones. The result will be a set of reference recordings from animals of known position and species, which can be used to evaluate, and enhance, passive detection, localization, and classification algorithms. Finally, controlled exposures of Navy-related sounds will be made to tagged animals to determine if, and under what conditions, deep-diving whales react to man-made sounds.

BENEFIT: The project research on short-term impacts of naval sound sources will provide critical data for developing protocols for operating these sources in ways that comply with federal environmental laws. Without this information, there is a risk either that these sounds may adversely impact protected populations or that protective measures taken as a precautionary measure because of ignorance may impact naval operations. Once passive acoustic monitoring has been tested and validated, it offers a non-invasive, cost-effective method to monitor vocal behavior and distribution of vocalizing animals for months before an operation, during the operation, and for months after the operation.

ACCOMPLISHMENTS: During FY01, this research team identified two promising field sites where research groups have been able to approach beaked whales very closely for photography and biopsy sampling. The first site visited, Abaco Island, Bahamas, did not provide collaborative opportunities with research teams already working in the area. The Ligurian Sea field effort, resulted in numerous sighting of *Ziphius cavirostris*, the highest priority species for the tagging. A handheld pole was tested for deploying the DTAG. The pole was also tested with bowriding dolphins, and were able repeatedly to lightly touch the dolphins as if tagging, with little reaction from the animals. These results lead to the possibility to tag beaked whales and dolphins. The project worked on an attachment for these animals that involves a more hydrodynamic fairing and an active suction system. DTAGs with 1.6 Gbyte of flash memory were constructed, allowing an increase in data storage which will allow recording sounds at higher frequencies that should be more appropriate for these species. The team has also improved sensors, sensor conditioning electronics, and have tested our calibrations for calculating pitch roll and heading of the tagged whale.

TRANSITION: The results of this project will transition into the Navy's marine mammal protection program. The data will provide vocalization databases required to assess the probability of detecting animals on Navy ranges. In addition, the team will work with range acousticians and signal processors to provide a biological perspective.

PROJECT SUMMARY

PROJECT TITLE & ID: Acoustic and Visual Monitoring for Marine Mammals at the Navy's Southern California Off-Shore Range; CS-1189

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Hildebrand; University of California, San Diego – La Jolla, CA

FY 2002 FUNDS: $340K

DESCRIPTION: The Southern California Off-Shore Range (SCORE) is a region where naval operations are frequently conducted and where marine mammals are known to be abundant. The technical objective of this project is to compare methods for actively monitoring marine mammals within the SCORE region using the following four techniques: (a) Aerial surveys (visual), (b) Ship-based transect surveys (visual), (c) Sonobuoy-based mobile acoustic surveys, and (d) Continuous fixed-site acoustic surveys.

Simultaneous application of these techniques will allow their comparison to determine the combination of methods most suitable for long term monitoring of the SCORE range. In addition, this project will investigate the contribution of environmental factors, such as sea surface temperature, to make an environmentally based model for marine mammal presence. This research will allow for better understanding of marine mammal presence within SCORE and improve techniques for studying marine mammal presence at other sites of naval interest.

BENEFIT: There is a high priority Navy requirement for data on marine mammal locations and seasonal densities within areas of frequent naval operations. The acoustic population estimation techniques developed by this project offer the potential for efficient and economical monitoring of marine mammals. These techniques are a first step in understanding the impact of sound on marine mammal behavior. This is an area of intense research by the Office of Naval Research and the Chief of Naval Operations (N45) with respect to environmental compliance issues.

ACCOMPLISHMENTS: During FY01, progress was made on visual and acoustic marine mammal survey data collection, and on algorithm development for data processing. Shipboard expeditions and aerial surveys have been conducted to the SCORE region. During each of these expeditions visual surveys were conducted, sonobuoy acoustic data were collected, and autonomous acoustic recording packages were serviced. To improve the analysis of marine mammal acoustic data, two algorithms have been tested for automatic call detection: (1) energy summation triggering, and (2) matched filter spectral correlation. The first method involves increased energy levels in a defined frequency band to detect the presence of a marine mammal call. The second method sought a match with the known spectral characteristics of marine mammal calls by calculating the cross correlation between the signal and an idealized call in the spectral domain. Results show that the spectral correlation technique is significantly more accurate in detecting blue whale calls than the energy summation method. The spectral correlation method can match or surpass the performance of a human analyst, and we plan to proceed with its application for automated call detection.

TRANSITION: Research findings will transition for use by SCORE personnel as a real time system for marine mammal detection and classification, as a database of seasonal marine mammal presence within SCORE, and as a predictive model for marine mammal association with environmental conditions. Marine mammal density estimates, as a function of both time and location as produced by this project will be integrated into a planning tool for use by the Navy. Development of acoustic techniques for marine mammal population assessment will also transition into the larger marine mammal science community. Passive acoustic monitoring can be applied as a complimentary technique to traditional visual survey such as those conducted by the National Marine Fisheries Service (NOAA).

PROJECT SUMMARY

PROJECT TITLE & ID: The Evolving Urban Community and Military Installations: A Dynamic Spatial Decision Support System for Sustainable Military Communities; CS-1257

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Brian Deal; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2002 FUNDS: $320K

DESCRIPTION: Extreme urban growth and the resultant patterns of development outside military installations are undermining the military community's ability to maintain mission focus. Some military installations' economic and environmental contributions to the local community are becoming outweighed by perceived incompatibilities such as noise, dust, shared resource competition, land use, land value, and land availability. These arise as the local community expands and available resources become scarce.

This project will quantify the current and future impacts of urbanization on the operations and sustainment of military installations. A Spatial Decision Support System (SDSS) is used to identify the factors and variables that contribute to land-use transformation and the subsequent conflicts that can arise between the military establishment and adjacent private sector communities due to conflicting land-use goals. The SDSS includes the development of spatial, societal and environmental impact assessments. The creation of indicators of installation sustainability, using both mission and ecological oriented criteria, will be established. The SDSS will be applied to identify military installations most at-risk from rapid exogenous urbanization.

BENEFIT: This project will help elucidate where the threat of urban growth may negatively impact the military mission. Obtaining clearer understanding of the dynamic and spatial interactions between the military community's mission and land use needs, and the adjacent community's goals, planning policies and probable spatial growth patterns is an important step toward resolving some of these issues. Evaluating the urban transformations near military installations can illuminate future conflicts for military land use and resource managers.

The military can benefit from better planning tools for predicting exogenous and endogenous land use needs and their conflicts with installation mission requirements. While several urban systems models are available that could provide a basis for such a tool, they are either not explicitly spatial or they do not model the interacting systems in any significant or dynamic way. In many cases, the emphasis is on modeling simple changes in land-use patterns and not the underlying systems and the interactions that produce these patterns. This project focuses on the development of a dynamic and military specific Spatial Decision Support System (SDSS) that will improve the decision-making processes and land management practices of the military installations and adjacent private sector communities. The fundamental purpose of this work is the discernment of possible approaches to planning solutions that can help sustain the military missions and environments within the communities in which they exist.

ACCOMPLISHMENTS: This is a FY 2001 Late Start.

TRANSITION: The outcome of this project will provide MACOMs with an analytical and visually oriented methodology for determining where the threat of urban growth might negatively impact the military mission, how this threat will impact military operations, and possible strategies for mitigating these impacts.

PROJECT SUMMARY

PROJECT TITLE & ID: Alternative Future Scenarios: Phase 1 Development of a Modeling System; CS-1258

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mary Cablk; Desert Research Institute – Reno, NV

FY 2001 FUNDS: $100K

DESCRIPTION: Due to the number and variety of unintended consequences, urban development on lands adjacent to installations is currently among the most pressing challenges to military installations. These consequences include safety risks; noise; impacts to plants, animals, and cultural resources; dust emissions, and other air and water pollution; and installation-specific issues. The Department of Defense (DoD) has investigated the use of alternative future scenario modeling (AFSM) to predict and remediate potential impacts of civilian development on military bases. To improve transferability or the widespread use of this technology to military land managers, this one-year project will develop an information system, a tool for simulating alternative future scenarios. The information system will significantly reduce the complexity of the AFSM process by making the modeling component interactive, portable, iterative, and user-friendly. Ultimately, land managers and other decision makers will have a user-friendly tool that they can use to (1) identify variables that may conflict with the sustainability of military operations and (2) predict and evaluate environmental impacts and assess risks under alternative land use change scenarios.

BENEFIT: There are several immediate benefits from this project. First, an evaluation of existing models or programs (OO-IDLAMS, mLEAM, LUCAS) relative to the overall Alternative Futures Modeling process is exceedingly valuable for appropriate application of these models. The evaluation will serve to highlight the strengths and weaknesses of each as well as allow us to identify where efforts have been concentrated, where they have been successful, and where key components still need research and development. Components of these models may prove useful in the development of our AFSM tool. A second immediate benefit is that research into statistical and mathematical modeling for developing alternative futures that includes translation of user-input into functions to revise outputs demonstrates proof-of-principle. This same research contributes to the understanding of key processes, specifically the relationship between landscape level spatial data and potential or predicable urban development.

An installation unable to function in its training and testing or other mission charter due to unexpected events from outside forces such as urban expansion, may become a fiscal burden. Any measures taken to prevent negative impacts to installation function from outside influences may divert unexpected fiscal expenditures. Likewise, impacts to training, testing, or other military activities that serve the greater charge of national security, directly affect mission capability and readiness. Installations that are unable to carry out their mission are not only costly, but do not fulfill their charge. The proposed AFIS will be designed to minimize these potential and negative impacts of urban development outside of installation boundaries.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION: The Phase I advances to the AFIS will increase the transferability and usability of this technology to help installation managers make critical land management decisions related to urban development surrounding their installation. Another set of advancements (Phase II) to make this tool more user friendly is needed to fully transfer this tool to an installation management staff.

PROJECT SUMMARY

PROJECT TITLE & ID: RSim-A Regional Simulation to Explore Impacts of Resource Use and Constraints; CS-1259

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Virginia Dale; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2002 FUNDS: $427K

DESCRIPTION: The need for applying ecosystem management approaches to military lands and regions that contain them is critical because of the unique resources on these lands and the fact that conservation issues may jeopardize military missions if not appropriately managed. This project will address this critical need by enabling application of ecosystem management approaches to military lands and surrounding regions. The objective is to develop a spatially-explicit simulation model that will enhance the abilities of military planners to understand the implications of external land-use change, resource use and future development policy on the sustainability of military land and missions.

A Regional Simulation Model (Rsim) will be designed to integrate environmental effects of on-base training and testing and off-base development and other decision. Effects to be considered include changes in air and water quality, noise conditions, and habitats for threatened and endangered species and game species. The simulation environment will build upon on existing land-use change model and will be designed to be available to users via a web interface. The model will be provided in a gaming mode so that users can learn about the potential environmental repercussions of military and land-use decisions. The Rsim model will be developed and applied to the region around Ft. Benning, GA because of the large amount of data available for the installation and surrounding region and the cooperation offered by the base in developing and testing the model. However, the model will be designed so that is broadly applicable to DoD's environmental management concerns. A risk assessment approach will be used to determine impacts of and integrated risks.

BENEFIT: This effort is developing new ideas on: (1) Developing an approach that integrates processes that operate on very different temporal and spatial scales. Such an approach is critical for the management of diverse environmental resources required of DoD and other agencies. (2) Incorporating feedbacks between different aspects of the environment that operate at different scales is one of the biggest challenges of interdisciplinary research and resource management. (3) Optimization: Environmental research has been constrained by efforts to meet single criterion (e.g., protection of one species or keeping particulates below a certain level). Our approach allows consideration of several criteria at the same time dealing with air, water, noise and species. Acceptable land uses for DoD are those that maintain standards within all these categories, and we are devising a procedure for verifying that standards are maintained. (4) Advances required within each module: Improvements in the state of the art of assessing land-use changes on water quality, noise, air quality, and species and their habitats. (5) A regional perspective: Historically, environmental concerns have focused on impacts within the installation due to onsite activities. Impacts will be examined of the region on the installation, of the installation on the region, and potential feedbacks.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: As the completion of this project, land managers and planners will be able to use this user-friendly tool at Ft. Benning to help understand the implications of external land-use change, resource use and future development policy on the sustainability of military land and missions. Transition of this tool to other installations is dependent on the type and amount of data available in and around an installation, however, the methodology will remain relatively the same.

PROJECT SUMMARY

PROJECT TITLE & ID: Detection and Identification of Archaeological Sites and Features Using Radar Data; CS-1260

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Ronald Blom; NASA / Jet Propulsion Laboratory – Pasadena, CA

FY 2002 FUNDS: $316K

DESCRIPTION: Application of aerial and satellite radar data for archaeological inventory and evaluation has been limited for two reasons: (1) most cultural features are too small to be identifiable given the resolution of imagery produced from the radar data using current processing and post-processing protocols, and (2) until recently, imaging radar data have been only collected at a single frequency/polarization combination. This project will provide a nearly ideal environment in which the archaeological interest can be systematically determined, thus providing and characterizing protocols for data processing and interpretation adequate to detecting and characterizing archaeological sites. This project will identify the radar wavelengths, polarizations, and angles of transmittal that are most effective in detecting and characterizing a variety of archaeological sites and features under conditions that fall within environmental parameters common to much of the western U.S. Airborne radar data will be collected with a multi-band, NASA/JPL multi-polar radar instrument (AIRSAR) over San Clemente Island, CA. The resulting understanding of the behavior of radar in response to archaeological targets will provide the basis for the formulation of effective, transferable protocols for detection and evaluation of cultural resources on military installations in the western U.S.

BENEFIT: The protocols developed by this research will demonstrate and prove the utility of synthetic aperture radar to finding and evaluating archaeological sites. Those most readily identified by the refined technologies and protocols will be among the most important and challenging from a cultural resource management point of view: structural sites, sites with middens, and sites that have been occupied over an extended period of time or reoccupied repeatedly with the result of altering soils chemistry and vegetative pattern. Processes for radar bands and polarizations will be much better understood so that they can be better applied to finding and characterizing archaeological sites. The protocols will be in effect produce a pilot scale system for this application of synthetic radar technology to cultural resource management.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: If successful, the protocols developed will be transitioned to cultural resource managers to inventory archaeological sites in environments similar to those of San Clemente Island. Preliminary characterization of detected sites is also feasible. The next step in transitioning the technology is to modify the protocols for more heavily vegetated areas.

PROJECT SUMMARY

PROJECT TITLE & ID: Developing an Efficient and Cost Effective Ground-Penetrating Radar Field Methodology for Subsurface Exploration and Mapping of Cultural Resources on Public Lands; CS-1261

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Lawrence Conyers; University of Denver – Denver, CO

FY 2002 FUNDS: $179K

DESCRIPTION: Military installations are in need of an efficient, accurate and readily useable method for discovery, mapping and possible avoidance of cultural resources in order to sustain military readiness. To date, no near-surface geophysical method has shown to be fully effective in the discovery of buried cultural remains. Ground-penetrating radar (GPR) has recently proven to be very efficient at collecting data of buried objects in grids ranging up to 50x50 meters. This project will quantify and calibrate GPR for known archaeological features that are commonly found in many areas of the U.S. in order to make GPR a more exact and easy to use tool for the discovery and mapping of buried and invisible sites. GPR data will be collected at two facilities (TBD) using many different radar configurations. The data from the various radar configurations and environmental conditions will be used to discover optimum GPR collection and processing methods. These data will be compared to what is known about local conditions and the depth and composition of buried features. The final product will be a field and laboratory protocol that can be modified depending on the ground conditions encountered, and the depth and aerial extent of the target features. More accurate and efficient detection and mapping of buried cultural remains on DoD and DOE land decreases the reliance on traditional, arbitrary excavations that are both costly and destructive.

BENEFIT: This project will develop and refine the use of GPR technology in archeology that will be central to the design and implementation of future GPR studies in cultural resource assessment. The results will include a pre-data acquisition protocol for site analysis, which will allow researchers to predict conditions expected in the field and to adjust hardware and software configurations accordingly. Site analysis of this sort will promote both an understanding of GPR energy radiation and reflection in the ground and save money and time as conditions can be predicted and adjusted for in advance.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: A quantitative analysis of GPR reflections during differing conditions, allows for the production of a protocol for GPR data collection on DOE and DoD lands. The protocol can then be used by cultural resource managers for GPR mapping, producing accurate maps of buried cultural sites, quickly and accurately.

PROJECT SUMMARY

PROJECT TITLE & ID: Methods for Assessing the Impact of Fog Oil on Availability, Palatability, and Food Quality of Relevant Life Stages of Insect Food Sources for TES; CS-1262

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Dennis Strenge; Pacific Northwest National Laboratory – Richland, WA

FY 2002 FUNDS: $150K

DESCRIPTION: Important components of troop training exercises at military training installations are generation of fog oil "smoke" and maneuvers under obscurant cover. To comply with the Endangered Species Act, the impact of fog oil releases on avian TES (or surrogates) have been evaluated in both field and laboratory studies. Although no direct acute effects on avian species have been observed, concern has been raised regarding a possible indirect impact via reduction in insect populations used as a food source for these species. This concern arises from the fact that petroleum oils of similar composition to that of fog oil have long been used to kill insect pests. These oils particularly target soft-bodied insects, eggs and larvae, and flying adult forms that are important dietary components of several avian and bat TES inhabiting military lands. This project investigates the impact of wind speed and canopy structure (key factors identified in past fog oil deposition research) on fog oil deposition and insect toxicity and behavior through the use of wind tunnel tests providing reproducible exposures, which are difficult to obtain in field tests. The results measured will identify fog oil impact on insects based both on quantity and quality of food source for endangered birds and bats. The final product of this project will be a set of response functions describing mortality, morbidity, food quality and food availability of insect prey of TES in terms of oil deposition rate, average air concentration, wind speed during generations, and canopy structure.

BENEFIT: This study will provide a cost-effective (compared to field assessments) method for quantifying the potential impact of fog oil on the food base of TES inhabiting DoD lands where training activities are conducted. This will allow testing of prey species under relevant climatic and canopy conditions of specific TES. Because information on the effects of fog oil on important prey species of the red-cockaded woodpecker, several neotropical birds and two endangered bat species are tested in this project. The exposure-response data from the study will directly benefit risk assessment/management efforts for these species. This study will provide information relating exposure-response data to transport and environmental conditions for fog-oil smoke generation. This information will provide DoD installation biologists and regulators with whom they interface with a method to estimate the relative size of the zone of impact of fog. If the study indicates the potential for significant impacts on insects consumed by T&E species, the exposure-response data will allow estimation of the potential for impacts on T&E species as a function of fog-oil concentration, wind speed, and canopy. This information can be used to provide guidance to field personnel in use of fog oil during field exercises. Additional information of this type will aid in protecting TES in compliance with the Endangered Species Act, thereby sustaining land use and training and readiness mission capability.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The information gained from this project will be used by installation managers to make decisions about the application of fog oil during training exercises. The set of response functions describing the mortality, morbidity, food quality, and food availability of insect prey of TES in terms of fog oil deposition rate, average air concentration, wind speed during generations, and canopy structure provide the means to establish appropriate protocols for using fog oil and protection T&E species. The information will be useable with transport models and will be released to the peered reviewed literature, as well as, directly to Ft. Leonard Wood.

PROJECT SUMMARY

PROJECT TITLE & ID: Metal Ion Sensor with Catalytic DNA in a Nanofluidic Intelligent Processor; CS-1265 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Donald Cropek; U.S. Army Corps of Engineers Engineer Research and Development Center, Construction Engineering Research Laboratory – Champaign, IL

FY 2002 FUNDS: $100K

DESCRIPTION: Anthropogenic sources of lead (Pb) from military operations require active monitoring and sensing to ensure environmental compliance and protection. This project will create a highly selective and sensitive miniature sensor for Pb^{2+} by combining two recent advances: (a) catalytic DNA that is reactive only to Pb^{2+} and which can be tagged to produce fluorescence only in the presence of the metal, and (b) nano-scale fluidic molecular gates that can manipulate fluid flows and perform molecular separations on tiny volumes of material. This work will develop the chemistry needed to combine Pb-specific catalytic DNA with the molecular gates and the protocol for separating, sensing, and quantifying Pb^{2+} in a complex matrix. Success in the development of this prototype lead sensor lends itself to rapid development of other targeted chemical sensors based on catalytic DNA that are uniquely reactive to any other metal and organic compound.

BENEFIT: Successful results in this research will provide a sensor prototype that stands apart from current sensor technology for lead in water in terms of ruggedness, sensitivity, selectivity, reusability, and field operability. This minute device can be used in multiple environmental, industrial, and ecologically sensitive applications for real time, in-situ measurement of lead in water samples. The miniature dimensions and the predicted low cost of this sensor type allows for siting multiple sensors for complete characterization of complex systems. The resultant cost savings is nearly ten-fold over current snapshot methods of sample collection, transport, and laboratory analysis, in addition to the benefit of continuous unattended monitoring. Because identifying the Pb-selective catalytic DNA sequence is accomplished via a novel combinatorial search, success in the development of this prototype lead sensor lends itself to rapid development of other targeted chemical sensors based on catalytic DNA that are uniquely reactive to any other metal or organic compound. Thus, relevance of this research is magnified beyond Pb^{2+} to include field sensors for other chemicals of interest such as PCBs, PAHs, and other metals (e.g., Al, Hg, Cd, and depleted uranium).

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: If successful, the Pb^{2+} chemical sensor based on catalytic DNA, will provide the prototype for further study and applications to rapidly detect other chemicals of interest such as: PCBs, PAHs, and other metals (e.g., aluminum, mercury, cadmium, and depleted uranium). The prototype sensor will be deployable to DoD managers for the purpose of monitoring anthropogenic sources of lead.

PROJECT SUMMARY

PROJECT TITLE & ID: Miniature, Multiple Sensor Systems for Continuous Detection of Metals, pH, and Other Parameters; CS-1266 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. David Kidwell; Naval Research Laboratory – Washington, DC

FY 2002 FUNDS: $100K

DESCRIPTION: Sources of copper (Cu) from Navy activities such as antifouling agents on ship bottoms and dredging operations require active monitoring and sensing of individual copper (I and II) to ensure environmental compliance and protection. Due to the toxicity of copper especially in estuary environments, all sources of copper must be monitored to account for the relative impacts of the various sources. Current methods (i.e., atomic absorption using Method 7210 and 7211) measure total copper (Cu I and Cu II) including soluble and particle bound and do not measure the true toxicity known to result from Cu I. This one-year effort will develop a miniature sensor system based on ion selective electrodes and other electrochemical measurements that detects individually copper I, copper II, pH, temperature, conductivity, chloride (or sodium), and turbidity. Because the measurements are determined in seconds, this sensor package will be suitable for rapid surveying of the marine environment.

BENEFIT: All sources of copper must be monitored to mitigate the impact to the environment and to account for the relative impacts of all the sources. This sensor system will provide a prototype for a miniature, inexpensive, water monitoring system that can continuously and simultaneously monitor a number of variables.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: If successful, the miniature sensor system based on ion selective electrodes can be deployed to DoD managers interested in rapidly monitoring copper and other electrochemical parameters in the marine environment.

PROJECT SUMMARY

PROJECT TITLE & ID: Nano-Engineered Electrochemical Sensors for Monitoring of Toxic Metals in Groundwater; CS-1267 *(SEED Project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Zemanian; Pacific Northwest National Laboratory – Richland, WA

FY 2002 FUNDS: $100K

DESCRIPTION: This proof-of-principle study will develop a novel class of micro-scale electrochemical sensors for measurement of metal ion concentrations in aqueous streams. The sensors will be based on highly porous functionally coated electrodes. These materials afford significant capacities for adsorption of metal ions to functional ligands embedded in the electrically conductive coating. Selective electrodes have been fashioned at PNNL from chemical ligands in carbon paste or conductive polymer matrices. These electrodes are efficient and specific, but degrade over time due to depletion of the ligand-bearing material. The proposed electrodes bear the active ligands covalently bonded to high surface area supports, and thus will retain chemical functionality despite diffusion or abrasive wear. Specifically, this project will: (1) develop the fabrication technology to combine the desired conductive matrices, meso-porous supports, and adsorptive coatings; (2) test the materials for uptake of aqueous lead and mercury; and (3) demonstrate the sensitivity of the square wave adsorptive stripping voltammetry-technique using the novel electrodes to measure aqueous lead (Pb) and mercury (Hg) ion concentrations.

BENEFIT: The proposed sensors will: (1) increase frequency and precision in data acquisition, (2) provide a means to detect short-lived events, (3) allow for robust and inexpensive construction method, and (4) provide specificity for metal species of interest. In addition to its value for groundwater monitoring, a subminiature electrode, suitable for a microscale/microfluidic electrochemical sensor device for measuring metal ion concentrations would also be useful for many industrial applications. In particular, the sensor would have uses for monitoring of any aqueous waste stream likely to carry metal ion contaminants.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: If successful, the nano-engineered electrochemical sensors will be transitioned to DoD managers that are interested in monitoring Pb and Hg in groundwater. Further development of the sensor will provide opportunities to monitor other metals of interest. Just as for groundwater monitoring, the availability of selective in-line sensors would be of tremendous benefit to a broad range of industries.

APPENDIX D
Pollution Prevention Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Next Generation Fire Suppression Technology Program; PP-1059

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Richard Gann; National Institute of Standards and Technology, Building and Fire Research Laboratory – Gaithersburg, MD

FY 2002 FUNDS: $1000K

DESCRIPTION: Halon 1301, the predominant and critical total flooding fire suppressant installed in weapons systems, is no longer in production due to its deleterious effect on stratospheric ozone. The objective of this program is to develop and demonstrate, by 2005, environmentally acceptable and user-safe processes, techniques and fluids that meet the operational requirements currently satisfied by Halon 1301 systems in aircraft, ships, land combat vehicles, and critical mission support facilities. The results will be specifically applicable to fielded weapons systems and will provide dual use fire suppression technologies for preserving both life and operational assets. This effort leverages prior SERDP-funded research and the Research Development, Test, and Evaluation (RDT&E) infrastructure created under the ongoing Department of Defense's (DoD's) near-term research program.

The research approach consists of six parallel Technical Thrusts, closely integrated to achieve specific milestones within an 8-year time frame. This approach was developed collaboratively by government, industry, and academic experts in fire science, the contributing technical disciplines, instrumentation, testing, and Halon 1301-protected weapon systems. Following are the six Technical Thrusts, which embody 24 separate research elements.

1. Risk Assessment and Selection Methodology develops a process for choosing among alternative technologies by applying modern decision-making concepts.

2. Fire Suppression Principles establish the mechanisms of flame extinguishment using detailed experimental studies and computational models leading to new approaches for fire control.

3. Technology Testing Methodologies select, adapt, and develop test methods and instrumentation to obtain data on the effectiveness and properties of new suppression approaches.

4. New Suppression Concepts define new ideas for fire suppression based on chemical and physical principles.

5. Emerging Technology Advancement accelerates a variety of processes, techniques, and fluids that are currently under development.

6. Suppression Optimization develops the knowledge to obtain the highest efficiency of each candidate technology.

This is a "living" program, representing the best current thinking for achievement of the objective, yet adaptable as the knowledge base grows. There are always risks in such an undertaking. For instance, there might be no chemicals that perform well for all the desired properties; no new fire suppression technologies might emerge; optimization principles might not improve mediocre approaches sufficiently; and lab-scale measures might not adequately predict real-scale performance. This research is designed to provide the scientific understanding to maximize the likelihood of overcoming risk factors.

BENEFIT: The outcome of this program will be demonstrated alternatives to Halon 1301. This will enable DoD weapon system managers to remove their dependence on a key ozone-depleting substance while minimizing fiscal and operation barriers to implementation.

ACCOMPLISHMENTS: The NGP is developing both improved understanding to guide the search as well as identifying candidates worthy of further consideration. The following is a list of highlights achieved in FY01:

- NGP research has found that while halogenated agents are effective on a wide variety of laboratory flames, metal- and phosphorous-containing compounds are strikingly efficient on some and not on others, a problem that is now a research priority.
- Four tropodegradable bromocarbon extinguishants continue to perform well in successive screening tests; a search is underway for similar compounds with lower boiling points.
- There has been an improved method for estimating the atmospheric lifetimes of not-yet-synthesized compounds.
- NGP research has developed the bases for solid propellant gas generators that burn cooler with increased flame suppression efficiency.
- The baseline version of a CFD model of suppressant flow, a fire, and fire extinguishment in cluttered environment predicts the flow characteristics in a quarter-scale, smooth nacelle fixture under well-controlled conditions.
- Over 80 intumescent compounds have been identified that could reduce air flow in a nacelle in the event of a fire, reducing the mass of needed agent.
- A NGP instrument for rapidly measuring agent concentration during suppression has been successfully tested in a Bradley armored personnel carrier.
- The NGP methodology to quantify a fire suppression technology by its total, life cycle cost has been used to compare the existing halon 1301 system in a C-17 aircraft and a system of equal performance using HFC-125. The benefit of having either fire suppression system substantially outweighs its cost, and the difference in total cost of the two systems is modest compared to the total cost of owning and operating the aircraft.
- The NGP has assessed the current status of fuel tank inerting systems that had in prior decades shown promise for fuel tank inerting, giving their latest status, any history of testing or use, and any concerns with their implementation.

TRANSITION: This is an eight-year, comprehensive research and development (science and technology) effort with leveraged funding from all DoD Services, industry, and academia. Successful sub-projects will be further developed within this program. “Spin offs” to various weapons systems development programs are anticipated.

PROJECT SUMMARY

PROJECT TITLE & ID: Tri-Service "Green" Gun Barrel – A Physical Vapor Deposition for the Application of Environmentally Safe Coatings for Gun Barrel Bore Protection; PP-1074

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. John Vasilakis; U.S. Army, Benet Laboratories – Watervliet Arsenal, NY

FY 2002 FUNDS: $200K

DESCRIPTION: This project will develop an innovative dry (non-aqueous) process for the deposition of chromium or other materials equally suited to the bore protection of a gun barrel to replace the aqueous electrodeposition process. This novel process is called the Cylindrical Magnetron Sputtering (CMS) process. The project will result in an advanced technology demonstration addressing specific Army, Navy, and Air Force requirements in the plating of the Medium Caliber Barrels. Moreover, it will show that the work can be spun off to Large Caliber Gun Barrels and other applications including cylinders for recoiling mechanisms, aircraft landing gear, the oil processing industry, the power generation industry, and the mining and exploration industry.

CMS is a dry, environmentally clean technology capable of depositing chromium on gun tubes. It also has the flexibility to deposit other refractory metals and their alloys as well as being able to tailor the coating properties through the deposition thickness. Although the focus is on chromium, the deposition of alternate materials, such as tantalum will be evaluated. If chromium were deposited, environmental problems can still exist because a "consumable" chromium target would have to be made, most likely, by the same electrodeposition process that this project seeks to eliminate. Initial efforts will focus on developing the facility for investigating a single medium caliber size and the parameters required for depositing a well-adhered, uniformly-coated tubular section. Once established, the facility will be sized to accept the different caliber gun tubes provided by the Tri-Service partners.

BENEFIT: Current weapon systems and those currently being developed or planned will have gun tubes with chromium deposited on their interior/bore surface to protect the bore surface from the hot propellant gases and the mechanical effects of the projectile. Current technology relies on an wet process known as aqueous electrodeposition. The chromic acid used in the deposition process contains hexavalent chrome, a known carcinogen that is extremely expensive to manage and dispose. For example, in FY95 for large caliber barrels, the cost of wastewater treatment and sludge removal was $2.3M.

ACCOMPLISHMENTS: Efforts continue to investigate the deposition of tantalum on 25mm gun barrels. Improvements were made in depositing a more adherent and improved morphology tantalum. A combination of substrate temperatures and cleaning has obtained an alpha tantalum coating. The medium caliber tower is operational and has been successfully used to coat 45mm test hardware. This was done for the Future Tank Main Armament (FTMA) program. Through the development of diode shields (plasma) lower process pressures enabled the desired zone T morphology. With the new target design, substantial improvements to uniform deposition were accomplished. Circumferential deviation was less than 3%. The longitudinal variation was also very small although not as tight. These are substantial improvements over what was done in the past.

TRANSITION: There is Tri-Service support for the program and typical medium caliber barrels from each of the Services will be coated with the new process and test fired at each of their respective facilities. The program is also heavily leveraged with others from not only the environmental area, but also from gun barrel wear and erosion areas. Industry has provided information to the program regarding environmental costs and has indicated interest in applying the technology after development.

PROJECT SUMMARY

PROJECT TITLE & ID: Replacement of Non-Toxic Sealants for Standard Chromated Sealants; PP-1075

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Alan J. Fletcher; U.S. Air Force Research Laboratory – Wright Patterson Air Force Base, OH

FY 2002 FUNDS: $500K

DESCRIPTION: The objective of this work is to formulate and test candidate non-chromated sealants that will provide equivalent or improved properties as compared to the existing chromated sealants while meeting the requirements of MIL-S-81733C. An additional goal is to reduce the volatile organic compound (VOC) content of the materials by 65 percent.

Sealants are required in aircraft systems and on weapons to provide protection against corrosion, prevent moisture entry, provide a fuel barrier, and provide electrical insulation. Traditionally, sealants use chromium as the primary corrosion inhibiting substance. Chromium has been designated as hazardous and is targeted for elimination in order to comply with either current or pending Occupational Safety and Health Administration (OSHA) requirements. Most sealants also contain VOCs such as methyl ethyl ketone (MEK) and toluene. Under this project team's guidance, a chromate-free corrosion inhibiting sealant has been developed, tested and transitioned to the field. A new polymer has been developed that is characterized by properties beneficial to corrosion-inhibiting sealants: (1) Rapid cure times without a reduction in work life; (2) Pleasant odor; (3) Excellent rheological properties; (4) Excellent cure at low temperatures; and (5) High solvent resistance. The proposed work is directed towards use of this new polymer to formulate corrosion inhibiting sealants for all the types and classes of MIL-S-81733.

The approach encompasses the following tasks:

Polymer Selection and Optimization: This task will select, develop and optimize the base polymer system to be used for formulation development. The end result of the task will be a base polymer system that can be used to formulate non-chromated corrosion inhibiting sealants.

Selection of Curing Agents: This task will research, develop and formulate curing agents for the base polymers systems selected. A contract will be awarded to the sealant manufacture from Task 1 to research and develop curing agents for the base polymers systems selected. These curing agents will be non-chrome and minimum VOC compounds that provide the best curing mechanism.

Selection of Corrosion Inhibitor: This task will research, develop, test and optimize non-chromated corrosion inhibitors. A contract will be awarded to sealant manufacturers that have successfully completed Task 2 to research, develop and optimize corrosion inhibitors for their sealant system.

Selection of Sealant Systems: The requirement for each type and class of product will be reviewed by the team and the selection of one sealant system will be made for formulation into a sealant material that will meet the requirements for the intended use of each type and class of material.

Formulation of Sealant Compounds: This task will formulate sealant compounds needed to replace two of the types and classes found in MIL-S-81733.

Formulation Testing: Laboratory or pilot plant batches of each formulation will be tested for the critical requirements of type and class or sealant. Material samples will be provided by the sealant manufacturers to the Air Force Research Laboratory, the Naval Air Warfare Center, and the Army Research Laboratory. These laboratories will test the formulations to the critical requirements of each service.

Candidate Optimization: This task will optimize the promising formulations and will include optimization for ease of application, pilot plant manufacturing and testing, and scaled-up to production batches.

QPL Testing: This task will perform qualification testing on new formulations. Once a formulation has been finalized, qualification testing will be conducted on production batches of the material. MIL-S-81733 and AMS 3265 will be used for qualification test procedures.

BENEFIT: They include: (1) Reduced use of hexavalent chromium and VOCs; (2) Development of longer shelf-life sealant formulations; (3) Development of primerless sealant formulations; and (4) Expansion of technology enabling the replacement of other chromated sealants.

ACCOMPLISHMENTS: A prototype sealant formulation has been developed and comprehensively tested. A prototype base polymer and three corrosion inhibitor/accelerator formulations have also been developed. Application and performance properties were determined for the three base/accelerator combinations according to the requirements of AMS 3265. In addition, the corrosion inhibition properties of the three corrosion-resistant sealant combinations were evaluated using Prohesion Testing per ASTM G85.

TRANSITION: MIL-S-81733 will be revised and implemented throughout DoD to incorporate the new non-chromated sealant compound while meeting all the other specification requirements.

PROJECT SUMMARY

PROJECT TITLE & ID: Non-Polluting Composites for Remanufacturing and Repair for Military Applications; PP-1109

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Sands; U.S. Army Research Laboratory – Aberdeen Proving Ground, MD

FY 2001 COMPLETED PROJECT

DESCRIPTION: The technical objective was to research, develop, and demonstrate a unique, affordable, environmentally friendly family of polymer-matrix composite (PMC) manufacturing and repair technologies for stand-alone repair of current, soon-to-be-fielded, and future DoD structures. Repair concepts and technologies were demonstrated on DoD-specific problems, including: (1) Design and implementation of a non-autoclave repair procedure for the Army's complex integrated polymer composite lightweight armor designs used on the Composite Armored Vehicle (CAV) and the Crusader Self-Propelled Howitzer (SPH); (2) Development, demonstration, and documentation of a repair-friendly processing method for the remanufacture of the Navy's FY02+ fielding of the Advanced Enclosure Mast Sensor System (AEMSS) including multifunctional material development; and (3) Development of several advanced concepts for non-autoclave manufacture and repair of thin composite skins for aircraft and Army rotorcraft.

This project investigated a variety of novel composite processing and cure methods, including vacuum-assisted resin transfer molding (VARTM), the multi-resin co-injection process, electromagnetic PMC curing techniques, and novel portable radiation (ultraviolet and electron beam) cure techniques to solve pollution problems in composites re-manufacturing and repair for military applications. A key to success was tight control over temperature during processing, reducing residual stresses and providing a consistent glass transition temperature (Tg) and consistent mechanical properties using recently invented composite manufacturing techniques and optimizing them for repair of complex DoD PMC structures.

BENEFIT: Technologies will enable out-of-autoclave processing as well as reduction of emissions from adhesive bonding operations. Used in tandem, these techniques can substantially reduce pollutants and waste in composite repair and remanufacturing. There will be no need for recycling scrap and waste materials by enabling efficient material use and reducing the number of processing steps required for the manufacture of multi-functional PMC components (e.g., Crusader, CAV, and AEMSS) by up to 80 percent. In AEMSS alone, cost savings in excess of $10M over the next 6-7 years are anticipated. The electron beam cured materials are a significant improvement to autoclave cured composites because it affords localized curing in a damaged structure, which eliminates the need for high-VOC and NOx emitting autoclaves.

ACCOMPLISHMENTS: The project team has successfully prepared two electron beam cured aircraft access panels using the methacrylate/epoxy-amine two-stage resins. Repair demonstrations on aircraft panels were demonstrated using EB cured adhesives developed by API on subcontract to Northrup Grummar Corp. (NGC). Additionally, a team from Drexel and the US Army Research Laboratory successfully tested a real-time spectrometer for measuring extent of cationically initiated cure of epoxides at the Boeing Radiations Effects Laboratory in Seattle, WA. The new experimental data will help the developers to prepare more idealized resin systems and address much needed improvements in hot/wet service performance for these materials types. Finally, a third generation of cost modeling was completed using SimProcess to calculate the total cost and cost savings associated with e-beam curing for aircraft structures. The current comparison evaluates wastes associated with VARTM processing of a traditional vinyl ester and compares this to wastes generated using e-beam cured epoxide reins. The total manufacturing costs are significantly higher with e-beam resins due to the high costs of the starting materials.

TRANSITION: Systems of interest for the application of these novel manufacturing/repair methods and for specific demonstration of the technologies during this program include Army helicopter blade repair with the new Aviation and Missile Command and Corpus Christi Army Depot (CCAD); the Navy's mast enclosure redesign, remanufacture, and repair procedure development with the Naval Surface Warfare Center; and Navy/Air Force aircraft skin non-autoclave manufacture and repair through Northrop Grumman and Science Research Lab.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmentally Advantaged Substitutes for Ethylene Glycol for Aircraft Ice Control; PP-1111

PRINCIPAL INVESTIGATOR & ORGANIZATION: Ms. Carolyn Westmark; Foster-Miller, Inc. – Waltham, MA

FY 2001 COMPLETED PROJECT

DESCRIPTION: The technical objective of this program was to develop a high performance, environmentally benign aircraft anti-icing fluid which can be safely released to the environment without capture, control, and post-treatment of the runoff. Specific objectives were to: (1) Develop a molecular modeling approach which allows for prediction of non-Newtonian viscosity behavior of materials based on their chemical structure; (2) Develop a non-toxic, non-Newtonian thickening agent with enhanced performance capabilities for anti-icing fluids, particularly extended holdover times; (3) Select low environmental impact additives for performance enhancement; (4) Demonstrate that the anti-icer formulations are compatible with military aircraft materials and weapons systems; (5) Demonstrate the ability of the anti-icing formulations to prevent ice formation for extended periods of time in simulated adverse weather environments; (6) Predict the water quality impact of new anti-icer formulations at actual airfield sites using computer modeling and laboratory analysis of key environmental parameters; (7) Determine any potential health/safety risks of anti-icing formulations; and (8) Develop cost-effective anti-icing formulations by screening out excessively costly materials throughout the testing program. The most promising freezing point depressants from an earlier Air Force funded Small Business Innovation Research (SBIR) Phase I program will be used as a basis for anti-icer formulations. The Foster-Miller strategy to develop environmentally advantaged aircraft ice control materials involves two key elements: (1) Identification of ice control material formulations which are inherently less damaging to the environment than current formulations; and (2) Development of efficient, high performance fluids which require less material to accomplish the objective of protecting aircraft surfaces from ice accretion.

BENEFIT: The project benefits include: (1) Drop-in, fully characterized, environmentally advantaged replacement for ethylene and propylene glycol based aircraft deicing materials; (2) Elimination of the cost of capture/treatment of effluent from aircraft deicing processes; (3) Reduction of material cost for aircraft deicing processes (since high efficiency fluids require less material usage); and (4) Increased flight safety and mission readiness. Additionally, this project will provide a model for non-Newtonian viscosity prediction based on the chemical structure of compounds and a model for predicting the impact of changes in ice control material formulation on runoff water quality at actual airfields.

ACCOMPLISHMENTS: Demonstrated performance comparable to industry leading fluids in light to moderate natural snow condition and evaluated aquatic toxicity of several full anti-icer formulations. The project also finished evaluation of surfactants and recommended deicing fluid candidate formulations for WSET screening.

TRANSITION: All Services and the commercial airline industry will be apprized of initial results. Massachusetts STEP program is assisting in the coordination with stakeholders. Formal product qualification testing is being conducted by Octagon. Commercial airlines field test will be conducted after product qualification. ESTCP funded demonstration and validation at military base will be proposed.

PROJECT SUMMARY

PROJECT TITLE & ID: Sol-Gel Technology for Low VOC, Non-Chromated Adhesive & Sealant Applications; PP-1113

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. James Mazza; U.S. Air Force Research Laboratory – Wright Patterson Air Force Base, OH

FY 2001 COMPLETED PROJECT

DESCRIPTION: The primary objective was to eliminate the volatile organic compounds (VOC), chromates, and strong acids typically found in the metal surface treatment and priming steps conducted prior to application of adhesives and/or sealants. Secondary objectives were the reduction of hazardous wastewater streams associated with current processes and improved performance compared to these processes.

This project developed, evaluated, and field-demonstrated nonchromated, zero VOC sol-gel processes for adhesive and sealant applications. The sol-gel processes developed replaced the current approaches that are high-VOC and/or use chromates. They also eliminated the current use of strong acids and reduce the waste streams associated with the existing processes. This project built on recent work using sol-gel technology to deposit thin organic-inorganic coatings on metal surfaces to develop good adhesion between the metal and subsequently-applied polymers (primer, adhesive, or sealant) via covalent chemical bonding.

The tasks (three adhesive bonding and one sealant adhesion promoter/primer) were:

1. Find an environmentally friendly pretreatment/primer system that can be implemented in the near term by optimizing a sol-gel surface preparation that is compatible with experimental waterborne adhesive bond primers. This was accomplished by sol chemistry optimization and by developing application procedures with emphasis on the surface activation drying/cure steps. Epoxy adhesives were the primary focus, although polyamides may also be evaluated for titanium.

2. Develop a one-step process that combines the adhesive primer and sol-gel surface treatment into one consolidated interfacial layer. Findings regarding the important process variables identified in Task 1, such as surface activation for the various metal alloys, were used to develop an application procedure. This approach eliminated the need for a separate primer step.

3. Evaluate the sol/primer mixtures of Task 2 as traditional adhesive primers.

4. Leverage the sol-gel work for adhesive bonding to develop adhesion promoters for sealant operations. The highest priority area was replacing the high-VOC primers used with silicone sealants with a zero-VOC sol-gel alternative. A second priority was to develop a universal adhesion promoter for polysulfide and polythioether sealants to promote adhesion between these sealants and various substrates as well as adhesion between the two sealant types.

BENEFIT: Developing new nonchromated, zero-VOC adhesive and sealant surface preparation and primer technologies under this program will have a major impact on both cost and performance of military and commercial aircraft. Reductions in the use of hazardous materials and reductions in wastewater will be significant across the various DoD depot and field-level facilities. The new sol-gel processes are expected to provide increased bondline strength and/or durability for many applications; this will improve aircraft performance, decrease downtime and maintenance labor hours associated with reworking poor repairs, and enhance operational readiness.

ACCOMPLISHMENTS: USAF personnel demonstrated the grit-blast/sol-gel process during installation of bonded boron/epoxy doublers to repair fatigue cracks around fuel vent holes in lower wing skins of F-16 aircraft. Prior to the repairs, tensile lap shear (ASTM D 1002), floating roller peel (ASTM D 3167), and wedge (ASTM D 3762) tests were conducted with the FM 300-2 adhesive used for this application. All tests indicated good results, with grit-blast/sol-gel outperforming the grit-blast/silane process used previously for vent hole repairs. The repairs took place at the depot in Aalborg Denmark during July and August. The repair installations were successful and demonstrated the benefits of the sol-gel preparation compared to the process typically used for these types of repairs. The sol-gel process saved about 3 hours per repair and eliminated the volatile solvents associated with the adhesive primer step since the waterborne BR 6747-1 from Cytec Fiberite was used. The demonstration also used new sol-gel kits from AC Tech.

TRANSITION: Further testing at Navy Aviation Depots, Air Logistic Centers, and Army Depots is anticipated after initial successes are demonstrated. Project has been transitions to ESTCP FY02 New Start Project.

PROJECT SUMMARY

PROJECT TITLE & ID: Visual Cleaning Performance Indicators for Cleaning Verification; PP-1117

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Bruce Monzyk; Battelle – Columbus, OH

FY 2001 COMPLETED PROJECT

DESCRIPTION: The visual cleaning performance indicators (VCPI) are a combination of intense dyes and coupling agents (CA) that selectively attach to target contaminants on surfaces cleaned in Department of Defense (DoD) and Department of Energy (DOE) operations. This innovative technology promises to provide a widely-applicable, real-time, low-cost, quantitative/qualitative cleaning process monitoring technique. The implementation of such a technique will reduce hazardous and non-hazardous waste and processing cost by avoiding excessive as well as inadequate cleaning and by enhancing implementation of environmentally friendly cleaning alternatives.

The project consisted of three tasks that were carried out by Battelle in collaboration with Air Force Research Laboratory and Naval Surface Warfare Center-Carderock. In Task 1, the DoD partners helped identify target contaminants for large surface cleaning. Battelle then selected commercially-available CAs and dyes, that can attach to the target contaminants, using known science and with input from DoD partners on material compatibility. Task 2 consisted of feasibility testing of the VCPI concept. The DoD partners prepared coupons for testing and Battelle sourced the contaminant CAs and dyes. In Task 3, Battelle cleaned the VCPI-treated contaminated coupons to demonstrate a relationship between color intensity and residual contaminant level. The DoD partners performed application-specific cleaning to determine whether VCPI components are compatible with DoD cleaning operations and materials of construction.

BENEFIT: This innovative technology provides a widely-applicable, real-time, low-cost, quantitative/qualitative cleaning process monitoring technique. The implementation of such a technique will reduce hazardous and non-hazardous waste and processing cost by avoiding excessive as well as inadequate cleaning and by enhancing implementation of environmentally friendly cleaning alternatives.

ACCOMPLISHMENTS: In FY01, the project concluded that the VCPI concept is efficacious for monitoring contaminants during DoD large surface area cleaning (aircraft and ships) in that the VCPI dye only labels the contaminant and not the surface. The dye follows the contaminant through the cleaning process, has sufficient visual differentiation to guide manual cleaning activity, has good environmental and safety features, and requires very little, if any, modification of current procedures and training. The VCPI method was found to be an effective method to monitor several broad classes of contaminants on several surface material types, both painted and unpainted. The amount of dye required for contaminant labeling is far below levels considered as residuals for highly clean surfaces. The VCPI method clearly showed that for porous surfaces, hydrophobic contaminants (e.g., grease and oil) penetrate into the surface and are not completely removed using DoD cleaning protocols. If the VCPI technique is used to monitor such a process, then residual contaminant labeling dye is also left in the coating, thereby imparting an objectionable amount of color to it. This result also suggests that the VCPI technique would be ideal to use to select new cleaners and cleaning protocols for painted and other porous surfaces.

TRANSITION: Working with DoD/DOE Depots, Battelle will field test the technique specifically for aircraft cleaning, application of tiles and painting of shipboard surfaces, and application to critical cleaning for weapons manufacture and demilitarization.

PROJECT SUMMARY

PROJECT TITLE & ID: Supercritical Fluid Spray Application Process for Adhesives and Primers; PP-1118

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Marc Donohue; Johns Hopkins University – Baltimore, MD

FY 2002 FUNDS: $362K

DESCRIPTION: The project objective is to investigate and develop low/no-volatile organic compound (VOC), non-structural adhesives to substitute for the current high-VOC, non-structural adhesives used in military applications. It is estimated that 8.5 billion pounds of synthetic polymer adhesives are used annually, of which approximately 55 percent are VOCs. While the total DoD usage is not known, it is estimated that approximately 173,000 pounds of VOCs are released annually by Air Force aircraft operations. VOCs commonly used in applying adhesives include aromatics (e.g., toluene), ketones (e.g., acetone, methyl ethyl ketone), and others (e.g.,methanol, chloroform). They are ozone depleting substances which negatively impact worker health, safety, and environment. Environmental standards for these substances require hazardous material management including cost of permits and emission control equipment.

Conceptually, the UNICARB process is straightforward in that a concentrated solution of polymeric material (in this case the adhesive and adhesive primers), and other additives are mixed in-situ with high-pressure (in the range of 1000 psi to 2000 psi) carbon dioxide and then sprayed. In practice, the process is complicated because of the mixing of an incompressible, highly viscous material (polymeric material and solvents) with a highly compressible fluid of very low viscosity (supercritical carbon dioxide). The solvents are mixtures of fast and slow evaporating VOCs which are chosen specifically for their ability to dissolve the polymeric material, reduce viscosity, and aid in atomization and droplet coalescence on the substrate. In the supercritical spray process, supercritical carbon dioxide replaces that fraction of the organic solvent that is needed to give the viscosity reduction necessary for spray atomization. This is also the solvent that is the primary contributor to the high VOC emissions.

This project will adapt the UNICARB spray application process to adhesives in two ways: (1) Continuous process for use in a manufacturing setting, and (2) Portable hand held batch process for use in small jobs or repair scenarios. Each of these processes requires its own unique set of phase diagrams given that the portable device operates in dynamic conditions (the materials and pressures of the system are changing with time), whereas the continuous spray operation operates in a steady state mode (the system pressure and material compositions remain constant with time). Therefore, for each adhesive adapted to the UNICARB process, two different types of phase diagrams will need to be generated.

The goals of this 4-year project are to adapt six non-structural adhesives to both a continuous and portable UNICARB process. The following approach will be taken:

- The polymeric material and solvent constituents of the six adhesives will be evaluated for their compatibility to the process.
- The identity and proportion of the various high and low volatile solvent constituents comprising the present adhesive mixture will be determined.
- Once the phase behavior is determined the configuration of the batch and continuous process will be established and tested.

- Based on the above tests, formulation of the supercritical carbon dioxide-solvent-polymer mixture will be further investigated for optimization of performance properties and minimization of environmental impacts.

- After determination of the optimal adhesive formulations, both processes will be field tested on various applications at venues to be determined by the respective military collaborators for this project.

- For each adhesive that is reformulated and adapted to the UNICARB process, a concurrent effort will be made to develop the underlying thermodynamic and rheological behavior.

BENEFIT: The principle cost benefits of this project will be from reformulation of existing adhesives now used by the military, and reduction in environmental impacts associated with the VOCs. By re-engineering the UNICARB process to one that can be applied with a hand-held device, the military will be able to increase the number of applications and venues where environmental compliance can be achieved. The advantages of adopting this process include: reduction in VOC emissions; reduction in solvent costs; use of existing and proven adhesives and primers; more evenly distributed coatings; reduction in labor costs; reduction of worker health and safety costs; and, reduction of costs associated with hazardous material management respective to permits and emission control equipment.

ACCOMPLISHMENTS: In FY01 the fifth system, a low molecular weight primer based on polyalkylene glycol, has been identified and characterization is underway. Strength testing of neoprene formulations was completed by ARL and additional testing of other adhesives is underway. The sixth system will be polyisobutylene. This polymer is widely used in both adhesives and sealants due to its excellent chemical stability. Polyacrylates are good weathering polymers for non-structural adhesive applications. Due to their saturated chemical structure, these polymers are resistant to UV and oxidation degradation. Polyacrylates also exhibit good resistances to water and solvents. These polymers have been used as pressure-sensitive adhesives (PSAs) as well as contact adhesives. For PSA applications, the polyacrylates of choice is usually a copolymer. The most common acrylic monomers include ethyl acrylate, methyl acrylate, acrylic acid and acrylonitrile. For contact adhesive applications, acrylics are highly cross-linked to improve strength. Polyacrylates are cross-linked by using multifunctional monomers to carry reactive groups into the polymer chains. In the past, phase behaviors acrylic-based paint coatings have been investigated for use in the UNICARB® process by our research group. In this work, the phase behavior of acrylic-based adhesive systems are investigated to determine the potential for application use in the UNICARB® process. The following activities were accomplished this year:

- Kraton D 1107, an SIS polymer, was fully characterized.
- Kraton G 1652, an SEBS polymer, was started and some static and dynamic characterization was completed.
- A new acrylic polymer, Morstik 649, has begun to be characterized.
- Strength testing of neoprene formulations was completed by ARL.
- The sixth system in the study, polyurethane, has been chosen and discussions with appropriate manufacturers have proceeded.

TRANSITION: DoD participants are the Tank Automotive & Armaments Command and Aviation & Missile Command. The investigator plans to work with adhesive manufacturers and equipment companies.

PROJECT SUMMARY

PROJECT TITLE & ID: Critical Factors for the Transition from Chromate to Chromate Free Corrosion Protection; PP-1119

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Rudolph Buchheit; Ohio State University – Columbus, OH

FY 2002 FUNDS: $500K

DESCRIPTION: The overall goal is to acquire a fundamental understanding of the chemical and physical processes and mechanisms of corrosion protection by chromate-based coatings applied to metal surfaces with a specific focus on corrosion protection of aluminum alloys. This project comprises a four year fundamental research effort. Specific objectives are to: (1) Define a set of phenomenological and fundamental rules that describe the role of microstructural heterogeneity in chromate conversion coating formation and breakdown; (2) Define the relationship between chromate conversion coating structure and chemistry, and coating properties for coatings applied under non-ideal conditions such as those that exist during coating applications in manufacturing and military maintenance depot environments; (3) Determine the extent to which application method, coating age, and alloy substrate chemistry affect the self-healing nature of chromate coatings; and (4) Develop rapid, quantitative, and predictive tests to assess properties and performance of chromate conversion coatings.

BENEFIT: Chromate corrosion protection technologies are expensive to operate and generate much hazardous waste. The expected benefit of this research is an increased fundamental understanding of the mechanisms of corrosion protection by chromate-based coatings. Ultimately, this information will support the development of effective chromate-free alternatives.

ACCOMPLISHMENTS: Microcell experiments are underway to characterize the behavior of each intermetallic compound in chloride and chloride-chromate environments. Recent efforts focus on the cathodic inhibition mechanism of chromate coatings and the disappearance of this cathodic inhibition on aged coatings. Findings show that there is a considerable decrease in this component of corrosion protection by chromate conversion coatings. In wrought 7XXX alloys, damage-free focused ion beam (FIB) sectioning of corroded alloys is being conducted to determine the type of corrosion associated with the two breakdowns found in the potentiodynamic polarization curves of 7XXX alloys.

Scanning Vibrating Electrode Technique (SVET) was used to continue research to develop new diagnostic techniques in parallel to the development of new environmentally benign coating systems. SVET studies are being conducted to correlate with results using surface analysis techniques such as XPS an Auger. SVET tests were performed for the examination of corrosion activities and mapping of anodic and cathodic areas on the aluminum samples exposed to diluted Harrison solution.

TRANSITION: All Services and DoD partners will be appraised of initial results from this fundamental research and will be used to aid in modifying procedures and specifications for corrosion protection by coatings.

PROJECT SUMMARY

PROJECT TITLE & ID: Mechanisms of Military Coatings Degradation; PP-1133

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Steven McKnight; U.S. Army Research Laboratory – Aberdeen Proving Ground, MD

FY 2002 FUNDS: $1050K

DESCRIPTION: Military coating systems are usually repainted for the following reasons: loss of appearance (aesthetics, camouflage, cleanliness); chipping, peeling, debonding of the coating; and corrosion of the substrate. The primary technical objective of this project is to identify, model, and predict degradation mechanisms that lead to military coating system failures, which require depaint and paint operations over the life of the weapon system. An overall deliverable of the proposed effort would be pollution prevention via intelligent reduction of the paint/repaint frequency. The project is developing models of coating degradation and providing a scientific basis to develop new durable coating formulations that will help to achieve this goal. The complexity of the problem demands complementary studies to fully understand the degradation mechanisms. This project will investigate mechanisms of military coatings degradation used on aircraft (Navy), combat ground vehicles (Army, Marines), and support equipment (Navy, Army, and Marines). The primary focus will be on the primer/topcoat systems that are being fielded to comply with environmental legislation and regulations. Both accelerated tests as well as static and dynamic field conditioning to assess coatings degradation in military systems and environments will be investigated. Most prior coatings degradation work has focused on commercial systems and has attempted to relate accelerated lab tests to actual service conditions. The response of any coating system to the environment is complicated and depends on resin type, pigment-resin, primer-topcoat, and primer-substrate interactions. Each element must be addressed to fully understand the degradation mechanisms of the coating system as a whole.

BENEFIT: The end result of this project will be an understanding of the mechanisms that explain the degradation of organic coating systems when exposed to military type environments. These mechanisms will be modeled and included in a statistical method for accurately predicting the performance of coating systems. Furthermore, an extensive database is being produced and shared with DoD, industry, and academia that documents results from accelerated aging, static weathering, and dynamic weathering of the new water-reducible coatings systems that are targeted for insertion in the near future. A thorough and quantified understanding of the mechanisms of coatings degradation will promote further confidence in environmentally friendly coatings and thereby increase acceptance of these new systems. Improved confidence will result in faster implementation of the low VOC coatings on military platforms.

ACCOMPLISHMENTS: Recent results have demonstrated that environmentally friendly coatings may actually out perform solvent based systems in terms of durability. The WaterDispersable chemical agent resistant coating (CARC) color retention lifetime is upwards of 4 times that of current fielded Solvent Borne CARC, increasing the confidence in technology transition as well as financial benefits. The data is currently being applied to Global exposure models to aid in correlating artificial weathering with 'real world' exposure.

TRANSITION: The results and models will be transitioned by promoting their use, as bases for defining performance criteria, and in the contracts issued during the acquisition (or rebuild) process. Additionally, the models can be incorporated into materials specifications and/or manuals as criteria for qualification or use. Finally, standardization and industry acceptance of such models would be pursued using existing work groups and through existing relationships with materials suppliers.

PROJECT SUMMARY

PROJECT TITLE & ID: Primerless RTV Silicone Sealants/Adhesives; PP-1135

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Dean Martinelli; U.S. Army, TACOM-ARDEC – Picatinny Arsenal, NJ

FY 2002 FUNDS: $291K

DESCRIPTION: Room temperature vulcanizing (RTV) silicones, developed in the late 1940's, have played an important role in the design and superior performance of weapon systems (airplanes, missiles, electronics, ammunition, vehicles and nuclear weapons) developed by the DoD and DOE. A unique combination of properties has made them the material-of-choice for designers wanting to improve and increase weapon performance. RTV silicones are used as adhesives, sealants, coatings, heat insulators and encapsulating materials. For RTV silicones to achieve a high level of consistent adhesion to various substrates, a saline primer is applied prior to silicone application. These primers contain 90-98% volatile organic compound (VOC) solvents, which evaporate into the air. The objective of this project is to develop, evaluate, and transition a primerless self- bonding low temperature curable addition cured silicone, which eliminates the use of high VOC primers without compromising durability, compatibility, thermal resistance and long term stability. The technical approach includes four phases. In phase I, current addition cured silicones available off the shelf will be modified with a bifunctional adhesion promoter compound. In phase II, a less inhibiting adhesion promoter, based on structures defined by molecular modeling will be utilized in an attempt to develop room temperature curing systems. Laboratory adhesion evaluations will be used to establish "go/no go" criteria for technology development in phase II. To expand adhesion capability to a variety of substrate materials, including plastics, novel adhesion promoting concepts will be evaluated in phase III using guidance from molecular modeling predictions. Phase IV will demonstrate the use of a new primerless silicone formulation.

BENEFIT: This technology will eliminate traditional primers leading to: (1) Reduction of over 500,000 lb/yr of VOCs; (2) Avoidance of costs from waivers, deviations and fines associated with the use of non-compliant materials; (3) Savings derived from reduced hazardous waste disposal costs; (4) Improvement of throughput; (5) Reduction in inventory management costs; and (6) Cost savings from reduced purchasing, material handling and specification consolidation.

ACCOMPLISHMENTS: Completed spot adhesion testing including baseline tests with primer and on a variety of metal and plastic substrates. Continued fracture energy studies of aluminum bonded with unmodified and modified silicone adhesives as a function of surface preparation and environmental exposure. Initiated experiments to determine the durability of primed and unprimed-bonded aluminum substrates. Developed an adhesion promoter modified system that provides durable adhesive bonds to nylon. The modified formulation is an elevated temperature cure system. This adhesion promoter was found to provide durable bonds to nylon in previous studies as part of this effort but further development of this system was initially postponed, as it did not provide adhesion to Lexan® and Ultem®. A patent is currently being sought for this system. Conducted shelf life studies under refrigerated storage conditions on second-generation, succinate adhesion promoter system and on new third-generation AP5 adhesion promoter system designed to provide adhesion to nylon.

TRANSITION: The transition of this technology will occur through revision of military specifications (MIL-A-46106, etc.) and by modification of current data packages with engineering change proposals.

PROJECT SUMMARY

PROJECT TITLE & ID: Nondestructive Testing of Corrosion Under Coatings; PP-1137

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. John Weir; Northrup Grumman Corporation – Bethpage, NY

FY 2002 FUNDS: $413K

DESCRIPTION: Aircraft painting and repainting operations result in significant emissions of volatile organics, organic and inorganic hazardous air pollutants, and hazardous waste. Aircraft paints are routinely removed to reveal the presence of corrosion on the surface of metal structures and the aircraft is subsequently repainted. Surface corrosion on aluminum aircraft skins and around joints and fasteners is often the precursor to buried corrosion. The objective of this project is to develop nondestructive inspection techniques to detect the presence of corrosion under an organic film in order to reduce the amount of painting and depainting that is performed. This project will develop: (1) A spectral NDE technique employing an optical reflectance probe in the near/mid intra-red (IR) region combined with Directional Hemispherical Reflectance (DHR) and Fouier transform infrared reflectance (FTIR) integrated detector; (2) Wide-area spectral imaging (WASI) using spectral filters and high-resolution focal plane cameras to allow rapid initial assessment of sub-paint corrosion; and (3) a Scanning Kelvin Probe (SKP) electrochemical method employing a calibrated capacitance probe to indirectly measure corrosion potential across a surface. These inspection and measurement techniques will be used to target and map specific areas that require maintenance due to corrosion, thus eliminating the need to completely strip and reapply the exterior coatings. Challenges to be overcome include probe positioning and electrical noise. The technical approach includes five major tasks: (1) Baseline measurements of unexposed coatings and typical corrosion products to build up a database of standards; (2) Evaluation of aged aircraft components; (3) Optimization of measuring systems at varying levels of corrosion and their modification for field use; (4) Prototype verification (in conjunction with NAWCAD); and (5) Preparation of a transition plan for cost-effective applications.

BENEFIT: Minimizing the number of times the aircraft exterior coatings are stripped and reapplied provides substantial pollution prevention and cost saving opportunities. The inspection and measurement techniques provide a means to verify the condition of coating thus allowing for a switch to a condition-based rather than schedule-based maintenance and to verify the condition of the primer and surface preparation once the topcoat has been removed thus eliminating a portion of the rework that now routinely occurs.

ACCOMPLISHMENTS: The note worthy accomplishments included an evaluation of a vendor IR camera for adaptation to the WASI concept that demonstrated extremely high fidelity images of both corrosion pits and fatigue cracks. Fatigue cracks down to .030 inches in length could be directly observed in real time under coatings. Additionally, corrosion pits down to approximately .001 inches could be observed utilizing the same IR camera system. Part numbers of aerospace fasteners and parts could be directly and easily read under coatings, demonstrating additional quality control capabilities of the system. The electrochemical techniques investigated included localized impedance spectroscopy, conventional Volta potential measurements with Kelvin probe and Volta measurements in ionized air. These electro-chemical techniques demonstrated that corrosion could be detected clearly under 3.4 mils of paint. Local images of the corrosion hidden under the coatings were also produced during the detection process further demonstrating the potential for scale-up with real time images, as well.

TRANSITION: Weapon systems will be identified that can use the spectral imaging and electrochemical measurement technologies to assess the condition of underlying substrates relative to corrosion without coatings removal.

PROJECT SUMMARY

PROJECT TITLE & ID: Cleaning Verification Techniques Based on Infrared Optical Methods; PP-1138

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. David Otteson; U.S. Department of Energy, Sandia National Laboratory – Albuquerque, NM

FY 2002 FUNDS: $100K

DESCRIPTION: The objective of this project is to develop a real-time method to provide both qualitative and quantitative assessments of surface cleanliness for a wide variety of military cleaning applications. The introduction of new environmentally acceptable solvents for traditional chlorinated hydrocarbon materials has produced major uncertainties in standard cleaning procedures. As a result, many applications overutilize solvents that in turn, leads to the additional usage, handling and disposal of hazardous materials, while also wasting personnel operating time. Currently, the detection of surface contamination on reflective surfaces is most convenient and rapidly done by the Fourier transform infrared reflectance (FTIR) method which provides both quantitative and qualitative information on surface coatings. Specifically, the project will: (1) Develop a prototype, on-line widely tunable infrared laser based instrument with high speed surface-imaging capability but with limitations on the number of detectable organic contaminants; and (2) Optimize an FTIR based instrument with high sensitivity for organic species on a variety of surfaces, but with limitations on speed and surface coverage for real-time analysis of surface contaminants at very low level of concentrations. The proposed instruments will differ in the nature of the information they provide. The first will produce images that directly indicate the spatial extent and location of contamination. The second will provide a spectrally-resolved measurement of the surface reflectance at a single point.

BENEFIT: This project will develop two IR optical methods that address the need for new surface cleanliness analysis technologies. The methods will be able to: (1) Operate in real-time and will be useful in process monitoring and control; (2) Provide qualitative and quantitative output for comparative assessment of cleanliness levels (both quantitative amounts and species present); (3) Handle a wide variety of military specific applications, such as repair and remanufacturing processes at repair depots; and (4) Measure cleanliness levels such that they can be related to required materials property requirements for various surface preparation processes (e.g., repair or application of protective coatings).

ACCOMPLISHMENTS: The laboratory infrared-laser imaging instrument demonstrated the successful detection of a variety of contaminants common to defense depot repair and refurbishment operations. Samples were examined, and contaminants were mapped on the surface in good agreement with average values obtained from FTIR reflectance and weight gain measurements. Construction has begun of the prototype laser imaging instrument with most of the required components placed on order. The design and fabrication of an improved, portable FTIR instrument has been successfully completed in cooperation with Surface Optics Corporation (SOC). This instrument incorporates grazing-angle reflectance for maximum sensitivity to surface contamination, and was thoroughly tested in comparison with laboratory research instruments. Two successful field demonstrations were conducted showing instrumental detection of residual contamination on aircraft surfaces prior to, and in some cases, following standard cleaning procedures.

TRANSITION: Transition to both research and development organizations and DoD end users will be integrated over the life of the project through field testing at DoD facilities, communicating the results to DoD and DOE users, and aggressive pursuit of commercialization.

PROJECT SUMMARY

PROJECT TITLE & ID: Non-Structural Adhesives Requiring No VOC's; PP-1139

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Claude Selitrennikoff; MycoLogics – Denver, CO

FY 2002 FUNDS: $345K

DESCRIPTION: Currently available adhesives include epoxy-polyamides, polyurethanes, organo-silanes, cyanoacrylates and polyvinyl acetates. These often require toxic volatile organic compounds (VOCs). Commonly used VOCs include toluene, methylethylketone, acetone and xylene. In sunlight, VOCs and nitrogen oxides produce ozone. Other VOC interactions contribute to the formation of photochemical smog. Non-VOC adhesives would substantially reduce this form of air pollution. The search for strong, environmentally compatible adhesives has turned to such examples in nature as the tenacious adherence of barnacles and mussels to rocks. Although the properties have indeed been spectacular, production of these adhesives on a commercial scale is problematic. The objective of this project is to use microorganisms as a source of novel adhesives which do not include any toxic VOCs. These natural compounds will be environmentally safe yet still meet physical property performance requirements for numerous DoD applications.

BENEFIT: The Army, Navy and Air Force use non-structural adhesives for gaskets, instrument panels, textiles, packaging and labeling. Medical applications include biocompatible tissue augmentation, wound closure and drug delivery systems. DoD will realize significant cost savings from compliance with environmental regulations and the decrease in medical costs associated with the use of VOCs.

ACCOMPLISHMENTS: Three hundred and fifty microorganisms were screened for production of adhesives. Five were found producing adhesives with tensile strength greater than 500 psi on bare aluminum. One adhesive was selected for the focus of work during the final section of the project. With identification of the polymer backbone and completion of associated tasks, attention has shifted to acquiring data critical to scaled-up production. The first step was to collect data in the 5 and 15 liter laboratory fermenters. The purpose was to provide a basis for later work in 1000 liter fermenters needed for production of sufficient adhesive for field trials.

Several runs were made to determine parameters associated with production of high levels of adhesive. Absorbance at 600 nm, pH and product amount were recorded at intervals. The adhesive strength of the product was determined on samples taken at 24, 36 and 48 hours. Adhesive strength did not vary significantly among the time points but there was significantly less product recovered per unit volume at 24 hours as compared with either 36 or 48 hours.

TRANSITION: A transition team meeting provided valuable input to help ensure the objective adhesives will be useful to DoD. The adhesives will be tested to qualify them for Army, Navy, Air Force and DOE application as well as for use in the private sector.

PROJECT SUMMARY

PROJECT TITLE & ID: Electro-Spark Deposited Coatings for Replacement of Chrome Electroplating; PP-1147

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Andy Goetz; U.S. Army Armament Research, Development, and Engineering Center – Picatinny Arsenal, NJ

FY 2002 FUNDS: $200K

DESCRIPTION: Chrome electroplating is one of the most widely used surface treatment processes throughout the military services. The current alternative technologies, such as high velocity oxygen fuel (HVOF) process, are gradually replacing chrome electroplating for some applications. However, there currently exists a need for alternate technologies where alternate technologies such as HVOF coatings cannot be applied. Electro-spark deposition (ESD), a novel coating technology, is a pulsed-arc, micro-welding process that uses short-duration, high-current electrical pulses to deposit, with very low heat-input, a consumable electrode material on a metallic substrate. The short duration of the electrical pulse produces very rapid solidification of the deposited material resulting in a true metallurgical bond while maintaining the substrate at ambient temperatures. The process releases no hazardous wastes, fumes or effluents, is cost-effective, requires no special chambers, spray booths or operator protection, and eliminates the hydrogen embrittlement problems that can occur with some substrates. The objective of this project is to develop process control sensors, process parameters, equipment, and techniques using ESD to coat inside diameters and other difficult geometries with robust wear and corrosion-resistant coatings that will replace current chromium electroplating applications. The technical approach consists of developing the process parameters for selected material coatings required for specific military applications, and the process control sensors and algorithms necessary to achieve those parameters in non-line-of-sight applications. The components will be tested as part of the process optimization efforts, using specific test conditions defined by the military services.

BENEFIT: This will complement current replacement technologies, such as HVOF, by allowing coating of non-line-of-sight geometries that HVOF and other thermal-spray processes cannot coat. Cost benefits include: low capital expense (approximately $30K) compared to new Cr-plating lines (greater than $1 million) or HVOF (greater than $400K); elimination of waste disposal costs, $0 for ESD compared to greater than $10 million per year reported for Cr-plating for the Army alone; reduced or eliminated surface preparation costs relative to either Cr-plating or HVOF processes; and savings from portability of process to allow use in field or shipboard to coat or repair components in-place, with minimum set-up.

ACCOMPLISHMENTS: The project has demonstrated a crack free Stellite coating. Fatigue samples for testing are currently being prepared for shipment to the lab. Work resumed on developing process controls for automated non-line-of-sight coatings. Force controls have been refined to the point that contact forces can be set to within about 3 grams. Efforts are now being concentrated on developing multi-axis force controls for automated depositions. Audio signals are being developed for operators using manual deposition techniques in non-line-of-sight applications. In addition, all specimens were completed for the characterization of metallurgical properties, corrosion, and wear, and sent to Concurrent Technologies Corporation for testing and evaluation. Characterization of hardness and internal stress of the coatings was completed.

TRANSITION: This project will generate a working prototype of ESD system for non line-of-sight (NLOS) surface coatings, and protocols for process testing. Results of the process tests for the military Services will be reported to team members and to the technical community at the DoD Hard Chrome Alternatives Team (HCAT).

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Conductive Polymers as Environmentally Compliant Coatings for Corrosion Protection; PP-1148

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Peter Zarras; Naval Air Warfare Center – China Lake, CA

FY 2002 FUNDS: $500K

DESCRIPTION: Corrosion prevention using new conductive polymer (CP) coating materials will be the focus of this project. Environmentally compliant formulations combined with a benign process for the application of these coatings will provide the DoD community with an attractive alternative to current chromate-containing coatings. For years the chromate-containing coatings have been used to treat aluminum alloys such as 7075-T6, 7075-T3 and 2024-T3. Many DoD platforms such as the F-18, F-16, F-22, Joint Strike Fighter, MV-22, CV-22, H-60, C-141, C-130, C-5, and P-3 Orion aircraft use these chromium treated alloys. Hexavalent chromium (Cr^{+6}) has been identified as a health threat, and because of its toxicity, is currently highly regulated. New EPA regulations governing air emissions and lower OSHA permissible exposure limits (PEL) have greatly reduce the levels of Cr^{+6} allowed to be discharged into the industrial environment where workers will risk exposure to this known carcinogen. Therefore, chromate-free coatings are needed that also exhibit equal or superior corrosion protection. Conductive polymer coatings provide such an opportunity to reduce these hazardous materials, eliminate Cr^{+6} from coating formulations, allow compliance with new environmental regulations, and reduce hazardous disposal costs while ensuring mission readiness and worker safety. Several key steps to demonstrate the concept are:

Preparation of CP Powders: The first phase of this study is to prepare kilogram quantities of demonstrated BAM-PPV materials at NAWCWD, China Lake, CA. Concurrent with this effort will be the preparation of 10-gram quantities of oligoaniline acrylate polymer (OAP) by Rensselaer Polytechnic Institute (RPI) at Troy, NY. The NAWCWD-prepared BAM-PPV has been well characterized and has shown conclusive evidence of corrosion inhibition from constant current (galvanostatic) and constant potential (potentiostatic) measurements. These electro-chemical studies were conducted in concentrated salt-water solutions and provided quantitative evidence in reducing the pitting corrosion of aluminum alloys. The procedure for scaling up these CP materials has been successfully demonstrated at the 200-gram scale in moderate yield and high purity. Scale-up to kilogram quantities will proceed using the same procedure. Purity will be demonstrated by the same characterization techniques as previously used for the multi-gram batches (NMR and DSC). One small batch of the water-borne polymer, WAM-PPV, has been prepared, hence there is risk in scale-up, however, no difficulties are anticipated. RPI will prepare multi-gram quantities of OAP. Copolymers will be prepared with monomers used in the paint industry such as butyl acrylate, methyl methacrylate, and ethyl hexyl acrylate. This synthetic effort will focus on control of the Mw of polymer to allow easy processability during coating applications.

Paint Formulations with BAM-PPV and Benign Applications of these Materials: CP will be prepared for use in three different chromate-free formulations/processes. Water-borne paint/primer formulations (using water-soluble polymers or water-emulsified polymers) will be coated onto aluminum alloy substrates 7075-T6, 7075-T3, and 2024-T3. BAM-PPV materials will be dissolved/dispersed in liquid CO_2 formulations and coated on the same coupons at NAWCWD. (OAP will not be formulated pending corrosion testing of the neat material.) BAM-PPV materials will be used in powder-coating formulations developed at NAWCWD and coated onto these coupons by the Naval Aviation Depot, (NADEP) Jacksonville, FL using their spray booths. These three processes eliminate all solvent VOC content. Some CP coatings will also have a topcoat, such as MIL-C-27725 (translucent polyurethane topcoat), to compare with current coatings.

BENEFIT: The expected payoff is fourfold: (1) Increased environmental safety by reducing toxic metals; (2) Increased endurance of military equipment subject to corrosion conditions (humidity, seawater, and salt spray); (3) Increased mission readiness; and (4) Significant cost savings by reducing painting/depainting waste treatment.

ACCOMPLISHMENTS: NAWCWD has now scaled up production to 1+ kg quantities of the starting monomer. This compound has been divided into two pots and will be polymerized using a new polymerization procedure. The initial polymerization study based on a 50 g quantity of monomer using tetrahydrofuran as the solvent, potassium-tert-butoxide as the initiator and carrying out the polymerization at -40C has improved the yield of polymer from 30 % to over 65 % yield. This process will be used to polymerize all monomers. In addition several new monomer synthesis reactions have been successfully carried out to obtain BAM-PPV. This new improved synthesis is being used to obtain monomers that can be used to produce WAM-PPV materials. Rensselaer Polytechnic Institute (RPI) has now successfully synthesized several new monomers containing the “blocked” aniline oligomers and polymerized via free radical polymerization.

TRANSITION: This approach is based on a tight feedback loop between industry and end-users to provide a fast-track approach to product development for fleet-wide use.

PROJECT SUMMARY

PROJECT TITLE & ID: Clean Dry-Coating Technology for ID Chrome Replacement; PP-1151

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Bruce Sartwell; U.S. Naval Research Laboratory – Washington, DC

FY 2002 FUNDS: $729K

DESCRIPTION: Chrome plating is heavily used throughout the DoD on almost any system subject to wear - aircraft, ships, tanks, guns, hydraulics, etc. In order to avoid all the high volume waste streams inherent in wet plating technologies, the research team proposed dry-coating methods - plasma sprayed WC-Co (Tungsten Carbide-Cobalt) for internal diameter (ID) as small as 1.5". Recent work funded by Defense Advanced Research Project Agency (DARPA), Office of Naval Research (ONR), and the commercial sector has shown that plasma spray with small (1-10um) or nanoscale powders (20 um agglomerates or 20nm particles) produces very smooth coatings with the porosity and adhesion of high-velocity oxygen fuel (HVOF). Development of suitable spray method for miniature ID guns will extend the plasma spray process to 1.5" ID to reach most of the actuator components, and modification of these guns may permit us to reach 1" ID for the smallest pins, hydraulic actuators, etc. For some applications, such as sidewalls of grooves in IDs, or very thin-walled, heat-sensitive components, the ESD process is likely to be more cost-effective. ESD is a consumable electrode micro-welding technology with heat input that is extremely small and limited to the surface layer, and it is ideal for small areas and difficult geometries.

The objective of this project is to develop an ID coating technology that is clean, can be used for rebuilds, and is environmentally acceptable. This will be accomplished in four tasks: (1) Conducting research on the deposition of smooth, high quality plasma spray WC-Co coatings on IDs greater than 2.5", using existing guns with small particles and with agglomerated nanoparticles, (2) Developing and testing new miniature ID plasma spray gun for use with small particles and nano-agglomerates which could drive the minimum coatable ID down to 1", and (3) Ensuring that the technologies not only provide good performance at an acceptable cost, but also fit the diverse needs of maintenance operations.

BENEFIT: The immediate environmental benefit of the thermal spray approach is the complete elimination of hexavalent chrome mist and the chrome-contaminated toxic wastes associated with both chrome plating, stripping, and masking operations. This coating method has the potential for significant cost reduction in both production and sustainment. In general WC-Co coatings last at least 2 - 3 times longer than hard chrome. This leads to lower frequency-of-repair, better mission-readiness, and the ability to keep a lower spare parts inventory. The much reduced production time over chrome plating gives faster turn-around in overhaul operations, also enhancing mission-readiness and reducing inventory requirements.

ACCOMPLISHMENTS: Coatings of WC-Co and tribaloy have been demonstrated inside 3" ID tubes using three different plasma guns designed for ID deposition. These coatings have properties (hardness, porosity, stress, etc.) that appear to be acceptable. Sulzer Metco has evaluated tungsten carbide coatings made with 15 different powders deposited with the Sulzer Metco F100 and F210 guns. NRC has characterized the operating windows of the three guns with various tungsten carbide and Tribaloy powders, measuring the temperature and velocity profiles of the particles. As a result of these initial evaluations the program will bring three coating formulations to test, WC-Co using fused and crushed powder, self-fluxing WC-Co, and Tribaloy 400.

TRANSITION: The project is designed to feed directly into an equipment and process development and demonstration/validation program that will be able to follow rapidly upon the completion of the SERDP program. The final deliverable will be a technical report detailing the plasma spray methods that are ready for demonstration and validation.

PROJECT SUMMARY

PROJECT TITLE & ID: Electroformed Nanocrystalline Coatings: An Advanced Alternative to Hard Chrome Electroplating; PP-1152

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Maureen Psaila-Dombrowski; McDermott Technology, Inc. – Alliance, OH

FY 2002 FUNDS: $498K

DESCRIPTION: Hard chromium coatings (0.25 to 10 mil thick) are used extensively for imparting wear and erosion resistance to components in both industrial and military applications. This is because of their intrinsic high hardness (600-1000 VHN) and low friction coefficient (<0.2). The most common means of depositing such hard chromium deposits has been through the use of chromic acid baths. Health risks associated with the use of hexavalent chromium baths have been recognized since the early 1930's, wherein skin irritation and inflammation were identified. More recently, such hexavalent Cr baths have been shown to enhance the risk of cancer of the lung and nose.

Electrodeposited nanoscale coatings of metals and alloys provide the method via grain-refinement (3mm to 100nm avg.grain size) and Hall-Petch strengthening, to produce hard coatings which meet or exceed the hardness and wear performance of current (hard) chromium plating technology. Of particular importance is that these properties are attained using more environmentally benign chemistries (e.g., Fe, Zn, and Co-based systems). The objective of this program is to develop and optimize an advanced nanoscale coating technology based upon modification of environmentally-benign conventional electroplating techniques which will yield coatings that meet or exceed the overall performance and life-cycle cost of existing hard chromium electroplating. The proposed nanoscale coating approach, which is based upon electroplating, would allow for the retention of numerous benefits associated with hard chrome coating technology (i.e., non-line-of-sight application, excellent coating adhesion, dimensional consistency and superior surface finish).

The technical approach will consist of a three-phase program. Phase I provides identification and preliminary experimental assessment of suitable nanoscale electrodeposition systems which satisfy the environmental objective and provide the mechanical performance requirements. This phase will focus upon identifying the most promising systems from an environmental performance and cost perspective. Phase II will deal with developing and optimizing the most promising systems identified in Phase I and will incorporate additional performance evaluation including wear, thermal stability, and corrosion testing. Phase III efforts will be focused upon the optimization of nanoscale ‘bore-plating’ techniques which represent key applications for the DoD.

BENEFIT: This program will allow the complete elimination of hexavalent chromium at rework, maintenance and manufacturing facilities within the DoD. DoD currently spends over $10 million dollars per year in hazardous material disposal costs associated with hard chrome electroplating. The proposed nanoscale coating approach would allow for the retention of numerous benefits associated with hard chrome plating technology (i.e., non-line-of-sight application, excellent coating adhesion, dimensional consistency and superior surface finish). In addition, this approach will allow for the use of existing hard chrome plating infrastructure within the defense sector. This will significantly reduce the time and cost to practical implementation. Moreover, the proposed nano-technology is expected to provide significant performance and life cycle cost benefits over current hard chrome plating technology.

ACCOMPLISHMENTS: The following is a list of highlights achieved in FY01:

- Documented initial emission and cost data for cobalt process. No significant emission. Costs compare favorable with hard chrome

- Experimental Test Matrix was established to optimize the process. Process variables include pulse parameters, current density, pH, temperature anode material, concentration of metal ions in solution, hypophosporus acid concentration, grain refiners, reducing agents, and complexing agents.
- Initial testing has started on process optimization. This work has focused on pulse parameters and current density.
- Preliminary corrosion and wear tests have been performed
- Identified Cobalt-Iron-Phosphorus (Co-Fe-P) alloy for Phase II of the Program. Thermal stability up to 425C. No cracks or pores. Good wear resistance potential. Good hardness. Also evaluating Co-Fe-Zn and Co-Fe-W alloys as possibilities.

TRANSITION: It is anticipated that the proposed nanoscale coating technology will fully utilize the existing hard chrome plating infrastructure (i.e., contractors, equipment, specifications, etc.) with minimum capital expenditure, thus significantly reducing the time and cost to practical implementation within the DoD. The specific deliverables from this project include an environmentally compatible electrodeposition process to replace hard-chrome electroplating, suitable electrodes and fluid delivery system for a DoD non-line-of-sight application, annual reports, peer reviewed articles and design guidance on further applications.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduced Particulate Matter Emissions for Military Gas Turbine Engines Using Fuel Additives; PP-1179

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Mel Roquemore; Air Force Research Laboratory – Wright-Patterson Air Force Base, OH

FY 2002 FUNDS: $976K

DESCRIPTION: It is estimated that U.S. military aircraft emit about 600,000 kg of particulate matter into the atmosphere each year. Most of this particulate matter is in the form of soot particles with diameters less than 2.5 microns (PM2.5). There is a growing body of evidence that these small particles cause both health and environmental problems. The technical objective of the program is to develop one or more fuel additives for JP-8, JP-5, and diesel fuels that will reduce both the mass Emissions Index, EI (M), (grams of PM2.5 emissions/kilogram of fuel) and the number density Emissions Index, EI (ND), (particle number density/ kilogram of fuel) of PM2.5 at the exhaust exit of military gas turbine engines by 70 percent. The additive should be benign to the environment and the fuel system, cost no more than $0.01 per gallon of fuel, and not reduce engine performance and life.

Three complimentary technical approaches will be followed concurrently in developing a PM2.5 additive: (1) Fundamental approach, (2) Quantitative Structure Activity Relationships (QSAR) approach, and (3) Select and test approach. The fundamental approach is to conduct basic experiments with additives that have shown a tendency to reduce PM2.5 emissions. The experiments are designed to give insight into the additive mechanisms so that improved additive formulations can be developed. The QSAR approach will be used to provide a mathematical formula that correlates PM2.5 reductions to molecular, chemical, and physical properties. The formula will be used to select the next generation of additives to be tested. The select and test approach involves obtaining additives from additive companies and testing them. The companies will be given the results of the additive tests so they can reformulate their additive package and submit it for the next round of testing.

BENEFIT: In the near term, these fundamental additive studies will support the SERDP sponsored NIST research on gaseous emissions and particulate formation for turbine and diesel engines. The insights gained from these studies will be valuable to the understanding of PM formation processes and provide other researchers with a valuable resource for the design of next generation PM mitigating additives. The fundamental experiments involve simple experimental geometries that can be easily modeled. That information will be useful in developing and designing low PM emissions combustors. Finally, an additive or additives will be identified which reduces PM emissions from gas turbine engines by 70%. In the long term, Base Commanders and managers will be able to meet military readiness and local air quality standards of the Clean Air Act Amendments (1990) and upcoming amendments to this Act.

ACCOMPLISHMENTS: The goal of this program is to develop fuel additives to reduce PM emissions from gas turbine engines. In FY01 the program focused on three primary areas: (1) Setup and Standardization of Laboratory Instrumentation, (2) Setup and Standardization of Laboratory Burners, and (3) Fundamental Studies of Additives. The task of fabricating a system for making PM number density and size distribution measurements using condensation nucleus counters (CNCs) and differential mobility analyzer has been completed. An instrumentation checkout study was conducted by directly comparing PM measures made with different instruments.

Laboratory burners and instrumentation were configured for the additive experiments. This has proven to be very challenging. To get a PM number density comparable to actual gas turbine engines, the single cup burner has to be operated at equivalence ratios greater than 1. After a 5-month concerted effort, the 95% standard deviation precision error has been reduced from 40% to less than 10% in the single cup CFM burner.

TRANSITION: The project will provide a new methodology for evaluating additives to reduce PM emissions from turbine and diesel engines and provide a fundamental understanding of PM emissions from turbine and diesel engines for military and commercial applications.

PROJECT SUMMARY

PROJECT TITLE & ID: Castable, Solvent-Free Red Phosphorus Smokes for Target Markers; PP-1180

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Daniel Nielson; Thiokol Propulsion – Corinne, UT

FY 2002 FUNDS: $33K

DESCRIPTION: Red Phosphorus (RP) is a material used historically for the production of certain types of target markers. Although mature and reliable, the current process involves the use of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs), which are usually quite flammable, electrostatic discharge (ESD) sensitive, and harmful and/or toxic if inhaled or ingested. The technical objective is to develop castable or pourable, chemically-cured RP formulations with sufficiently high binder content to totally eliminate the need for solvent processing aids, while concurrently mitigating ESD sensitivity. This must be achieved while still maintaining the burn characteristics and white smoke-cloud formation produced by existing RP formulations.

The project will initially evaluate three types of chemically cross-linked energetic binders in RP smoke formulations. Energetic polymers that will be evaluated are poly-azide polymers (e.g., glycidyl azide polymer), nitrate ester polymers (e.g., plasticized nitrocellulose) and inert polyether polymers with energetic plasticizers. The same core set of tests used to establish the rheology/processing characteristics, hazard sensitivity, structural (mechanical) integrity and ignition and combustion characteristics will be used to determine the binder system. The best performing RP smoke formulations will be evaluated as potential prototype target markers.

BENEFIT: There are many benefits of the proposed formulations and processes in comparison to the current ones. Advancements in terms of cost savings, increased safety, and environmental concerns are expected for the solvent process, cast process, solvent waste, and VOC usage. The proposed formulations and processes should also provide extended storage life, required smoke, and higher production efficiency. Castable RP smokes offer very low risk for transitioning to large-scale production. Extensive manufacturing infrastructure and capability exists in the private industry and government facilities to batch-mix and cast solvent-free compositions like those proposed for this program.

ACCOMPLISHMENTS: The candidate formations have been selected. Several candidate compositions have been identified which meet all hazards criteria. These compositions have been loaded into prototype hardware for a preliminary evaluation of explosive charge required to burst the prototype hardware. GAP/RP formulations have been tested in MK67 prototypes. Particle dispersion was too great using 0.58" diameter Comp C4 and Comp B explosive charges. Reduction of the Comp B diameter to 0.45" resulted in a more compact distribution of burning RP particles.

TRANSITION: The developed formulation and process will be transitioned to the demonstration and validation phase based on successful test and evaluation of fully configured Army, Navy, and Air Force red phosphorous target marking and obscuring rounds. The proposed technology could be transitioned to any industry with similar facilities, equipment and technical capability.

PROJECT SUMMARY

PROJECT TITLE & ID: Environmentally Compliant Sprayable Low Observable Coatings that Facilitate Rapid Removal and Repair; PP-1181

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Kovar; Foster-Miller, Inc. – Waltham, MA

FY 2002 FUNDS: $762K

DESCRIPTION: Since the enactment of the 1990 Clean Air Act Amendment, the U.S. military and aerospace industry has achieved large reductions in emissions of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) from aircraft coating application and removal processes. NESHAP set limits averaging approximately 400 g/L of VOCs for general aircraft coatings; however, specialty coatings, including radar absorbing material (RAM) coatings for low observable (LO) aircraft were exempt from the 1998 NESHAP implementation. Although many RAM coatings contain a very high level of VOCs (>600 g/L), the EPA agreed to exempt LO coatings due to a lack of suitable low VOC RAM substitutes and due to the comparatively low volume of usage at that time. Over the next decade, the U.S. military plans to deploy several new weapons systems that utilize low observable technology and to retrofit several existing systems to render them more "stealthy." As a result, the emission of VOCs from RAM coatings is expected to increase up to 2 million pounds per year.

This project will develop an innovative No-VOC Low Observable Coatings (NVLOC) system that will meet or exceed all current and projected DoD mission requirements for RAM coatings, and will effectively eliminate the generation of VOCs and HAPs in the initial application. It may be possible in subsequent work to render these No-VOC RAM coatings to be easily stripped / removed and reapplied in an environmentally benign manner. In addition this coating will permit improved, low-cost methods for spot removal and repair of these environmentally compliant LO coatings.

BENEFIT: The immediate environmental benefit will be the elimination of the disproportionate amount of VOCs and HAPs generated by the application of LO coatings. Successful implementation will result in a nearly 100 percent reduction in VOC emissions generated during the spray application of RAM coatings. Potential cost savings related to the elimination of VOCs is estimated to be between $9 to $30 million annually. These No-VOC coatings may also lead to a rapid, effective HAPs-free coating removal process. Radical reductions in labor hours are expected. More environmentally friendly coating removal processes may also be feasible in the future.

ACCOMPLISHMENTS: The project worked on evaluation and selection of No-VOC RAM coating components. These include: vinyl dioxolanes, reactive diluents for viscosity reduction, catalysts/photo initiators/light sources to promote free-radical cross-linking reaction of the pendant vinyl dioxolane reactive end groups, type and quantity of processing aids such as wetting agents and thixotropic agents and RAM fillers to achieve desired electromagnetic performance with minimal filler loading. Various backbones for vinyl dioxolane endcapped coating oligomer were also evaluated to tailor the properties of the No-VOC RAM coating to obtain the best performance in the application. Different backbones are being selected for our coating resin and coating experiments are starting. Work is in progress for the synthesis of the reactive diluent to be used. The identified components are currently going through preliminary testing.

TRANSITION: This environmental benign coating technology will provide a tremendous reduction in the life cycle cost as well as improved availability/mission readiness of LO aircraft with potential applications for other weapons systems.

PROJECT SUMMARY

PROJECT TITLE & ID: Ultraviolet Light Surface Treatment as an Environmentally Benign Process for Production, Maintenance, and Repair of Military Composite Structures; PP-1182 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Lawrence Drzal; Michigan State University – East Lansing, MI

FY 2001 COMPLETED PROJECT

DESCRIPTION: Polymer matrix composites (PMCs) are used extensively in many DoD applications. A wide range of both thermoset and thermoplastic matrices reinforced with various fibers and particulates are in use or planned for the future in land, sea and air weapon systems. In the majority of applications, the PMC is fabricated into structure using adhesive bonding technology that has to be maintained and repaired. In addition, paints and specialty coatings have to be applied to PMC surfaces for mission specific applications. Surface preparation of the external polymer surfaces of the PMC is critical to attaining adhesive bonding and paint or coating performance. Manufactured polymer, polymer composite, and metallic surfaces always contain undesirable compounds or additives that reduce the adhesive or paint film. The technical objective of this project was to develop a low-cost, high-speed, environmentally benign dry surface treatment method for the production and repair of military composite structures using ultraviolet (UV) light in ambient air. The technical approach included the following tasks: (1) Investigate the use of UV light treatment in air to clean and modify the surfaces of the typical PMCs used in DoD systems; (2) Determine the effectiveness of this surface preparation for the production and/or repair of adhesive-bonded PMC structures; and (3) Determine the environmental, cost, and performance benefits of this pulsed UV method as a new, environmentally benign processing method for the production and/or repair of adhesive-bonded and/or coated PMC structures.

BENEFIT: The potential advantage of this method is that it would eliminate volatile organic compounds, reduce or eliminate the use of solutions and detergents, and provide a robust surface that would enhance the wetting and spreading of paints, coatings, and adhesives on polymeric and inorganic surfaces treated by this method.

ACCOMPLISHMENTS: Investigated the use of UV light treatment in air to clean and modify the surface of the typical PMCs used in DOD systems. Determined the effectiveness of this surface preparation for production and/or repair of adhesively bonded polymer matrix composite structure. Determined the effectiveness of this surface preparation for production and/or repair of adhesively bonded polymer matrix composite structure

TRANSITION: A final report will be issued which provides an objective assessment of the viability of using this pulsed UV method as an environmentally benign surface treatment for PMCs. Standard chemical engineering process estimation methods will be used to estimate the potential cost of implementation for DoD applications.

PROJECT SUMMARY

PROJECT TITLE & ID: Investigation of MIC Materials for Electrically Initiated Lead Free Primers; PP-1183 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Ron Jones; Naval Air Warfare Center – China Lake, CA

FY 2001 COMPLETED PROJECT

DESCRIPTION: Primers containing traditional lead compounds and other toxic materials are a significant source of pollution that can endanger the health of production workers, end users, and others. These lead-containing materials and byproducts represent serious threats that can contaminate the atmosphere, the soil, and ground water. This project evaluated the use of a novel lead-free compound in the production of medium caliber electrically initiated primers for aircraft gun ammunitions. The ultimate end product was intended to be an electric primer composition that does not depend on the use of lead as a component and provides equal or better performance than current materials. The approach included investigating the electrical and thermal properties of the Metastable Intermolecular Composite (MIC) compounds to determine their effects on the performance of lead-free primers. After developing a functional primer mix based on the use of the MIC materials and the fabrication of test articles, NAWCWD Ballistics Test Laboratory conducted functional tests. The test program also included the determination of minimum and maximum voltage and current levels to achieve "no-fire" and "all-fire" conditions, under all appropriate conditions. The final step in the validation of the proposed design approach was to produce a small number of 20 mm rounds and test fire them.

BENEFIT: Significant health and cost savings benefits will be accrued through the elimination of lead in the manufacture of medium caliber ammunition primers. Health benefits will be experienced by those involved in the production of the lead containing energetic materials, those that assemble the primers, by the ultimate users of the ammunition and finally by those that would be involved in the clean-up of contaminated environments. The financial benefits will primarily be seen in the future and will result from the elimination of contamination and the resulting clean-up activities. There may be unknown technical or performance benefits that will not be known or recognized until the program has made measurable technical progress.

ACCOMPLISHMENTS: The project was successful in firing medium caliber ammunition with an electric primer composition that does not depend on the use of lead as a component. The project presented before the SERDP Medium Caliber Tactical Advisory Committee as was selected for further studies as a full SERDP 3-year project under the Green Medium Caliber Program.

TRANSITION: A sufficient number of rounds will be fired to produce a reasonable level of confidence that the interim design resulting from this initial exploratory development effort will produce satisfactory performance of the round and could be transitioned to a final configuration that meets the military Service's needs.

PROJECT SUMMARY

PROJECT TITLE & ID: Electrostatic Fuel Atomization for Gas Turbines to Achieve Reductions in Particulate Emissions; PP-1184

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. David Guimond; Naval Surface Warfare Center – Philadelphia, PA

FY 2002 FUNDS: $60K

DESCRIPTION: A quantum particulate matter (PM) emissions reduction is possible with implementation of electrostatic atomization technology into today's military gas turbine engines. Other benefits include improved fuel consumption at low power, reduced gaseous emissions, reduced carbon fouling, and quantum reduction in fuel pump parasitic loss and cost. Fuel atomization has a first order effect on the formation of PM in virtually all combustion processes. The objective of this project is to develop and evaluate the capability of electrostatic atomization fuel injection technology to achieve reductions in particulate and gaseous emissions produced during the combustion process in Navy gas turbine engines. The current technology consists of a dual orifice nozzle with electrostatic injectors. CFD Research, Allison, and the Naval Surface Warfare Center Carderock Division (NSWCCD) will perform a proof-of-concept test with an Allison 501-K gas turbine engine. Charged Injection Corporation will adapt the recently patented electrostatic atomization breakthroughs to the 501-K fuel injector primary nozzle.

BENEFIT: The goal of the project is to demonstrate an 80% reduction in PM2.5 with electrostatic fuel atomization technology. The baseline emissions of the engine will be compared with the emissions from the same engine after the electrostatic fuel atomization technology has been installed. In addition to emission reduction, the proposed electrostatic atomization fuel injection technology would provide a payback from improved combustion efficiency at part power operation at which ships typically operate. Navy ship propulsion gas turbine engines operate at 33 percent of full load power capacity, on average; similarly, ship service gas turbine engines operate at 50 percent of full load power capacity, on average. During typical part power operation at low to mid-range power levels, combustion efficiency is approximately 93 percent. With the electrically atomized fuel nozzle system, analysis indicates efficiencies of 98 percent. Annual savings per ship would be $120,000 (3 engines x $40,000). Thus the average savings over the fleet of 50 DDG51 ships would be $6,000,000 per year.

ACCOMPLISHMENTS: No FY 2001 accomplishments reported due to delays in project startup.

TRANSITION: At the conclusion of the project, NSWCCD will coordinate the transition of this technology to a Dem/Val program on a fleet ship service gas turbine generator set.

PROJECT SUMMARY

PROJECT TITLE & ID: A NIST Kinetic Data Base for PAH Reactions and Soot Particle Inception During Combustion; PP-1198

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. George Mulholland; National Institute of Standards & Technology – Gaithersburg, MD

FY 2002 FUNDS: $422K

DESCRIPTION: Polycyclic aromatic hydrocarbons (PAH) are key molecular precursors to soot formation, but there is little known about their rates of formation and evolution in a flame environment or the dynamics and structure of the transition from a large PAH molecule to an incipient soot particle. The overall objective is to develop a NIST chemical kinetic database and an accompanying particle formation model that will describe the transformation of fuel molecules to their desired end products of carbon dioxide and water and the undesired end products of PAH and soot. The specific processes to be considered are fuel breakdown to precursors and subsequent growth to PAH, key gas-phase PAH formation/destruction chemical reactions, and key PAH-to-particle transition steps. The database and model will contain experimental data collected in a shock tube and in a novel well-stirred reactor with flow "chopped" PAH injection. Both atmospheric and high-pressure experiments will be performed. The database will be rigorously evaluated and extended with the recently developed NIST CHEMRATE computer program. The deliverable will consist of chemistry and particle-inception models that can be used in computational fluid dynamic models of diesel and gas turbine engines.

BENEFIT: Manufacturers of military aircraft engines have a strong interest in understanding soot formation in gas turbines. The deliverable will be a publicly available NIST database and soot inception model adaptable for use in computational fluid dynamic (CFD) models of diesel and gas turbine engines.

ACCOMPLISHMENTS: Databases have been assembled and tested for the pyrolysis of heptane. A series of shock tube measurements are now being carried out using n-heptyl-iodide to provide product distribution starting with the n-heptyl radical. A major breakthrough was finding that soot from a post-flame inverse flame was similar in chemical makeup to the "early" soot observed by Fletcher and Dobbins in a laminar flame. The advantage of the inverse flame is that large quantities of soot can be collected allowing use of more quantitative chemical analysis methods than is possible with in-flame sampling of early soot. This data will be important for testing various models for PAH growth. A high temperature filter system and samples were collected at three temperatures, 25 C, 120 C, and 320 C to assess the effectiveness of minimizing the condensation of gas phase PAH. The mass measurements of the filters indicate that the majority of the material collected at ambient temperature from the inverted flame is volatile organic material.

TRANSITION: GE has agreed to monitor our progress, provide technical guidance when needed, and ensure that our efforts possess transition potential and remain relevant to the needs of aircraft engine designers.

PROJECT SUMMARY

PROJECT TITLE & ID: Computational Design of Corrosion Resistant Steels for Structural Applications in Aircraft; PP-1224

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Gregory Olson; QuesTek Innovations LLC – Evanston, IL

FY 2002 FUNDS: $865K

DESCRIPTION: In many structural applications for aerospace ultra-high strength steels are used because they can provide the lightest weight for highly loaded systems. These steels, however, lack adequate corrosion resistance and are commonly cadmium coated. The environmental problems with cadmium are intrinsic to the material itself, creating occupational safety and health (OSH) risks and raising maintenance costs throughout the life of all cadmium plated parts. Many items that are cadmium plated, such as landing gear, are damage intolerant, and sensitive to hydrogen embrittlement and stress corrosion cracking. This sensitivity makes stress corrosion cracking the primary failure mechanism for landing gear. This often causes significant collateral damage to an aircraft, even though the failure usually takes place while it is parked. New coating technologies developed to replace cadmium have not demonstrated reliability in preventing these embrittlement failures and inherently corrosion resistant stainless steels are not strong enough to be used in such highly loaded structures. The development of an ultra-high strength stainless with corrosion resistance and strength to meet the requirements for landing gear has been the focus of traditional alloy development efforts for many years without success. The traditional empirical approach has been too costly and time consuming to be effective. A new technique, using advanced computational materials modeling and systems engineering methods, known as Materials by Design™, was used to design an innovative new prototype stainless alloy during a SERDP SEED program. This prototype, termed S53, proved to be more compelling than any previously developed stainless for this application, warranting a full SERDP program exploring this alloy.

The overall technical objectives of the program are: (1) Explore appropriate processing standards for alloy production processes, component manufacturing processes, and overhaul and repair processes to provide the information required for manufacture of components of the alloy, and (2) Provide adequate test data for mechanical behavior, corrosion resistance, and embrittlement resistance and life cycle cost to prove the ability of the alloy to replace current, cadmium coated aircraft structural steels using standard manufacturing techniques.

BENEFIT: The largest impact will be on the reduction of life-cycle cost and toxic waste in DoD squadrons and maintenance depots. Derivatives of the new steel will also be valuable replacements in actuators and for sustainment of legacy systems, which is the reason that the Aging Landing Gear Life Extension program (ALGLE) is assisting in the activities of this program. In addition, this program will provide a clear demonstration of the Materials by Design methodology itself, which holds the promise of much faster and less expensive development of alloys to meet the needs of higher performance, lower cost of ownership, and environmental cleanliness. Engineers will no longer have to compromise their designs to accommodate materials that are available but can determine the materials they need to meet the challenge before them.

ACCOMPLISHMENTS: A SERDP SEED program has established the feasibility of designing a new structural alloy to meet these diverse requirements without coatings, and a complementary program is currently optimizing this alloy composition. The second generation high-performance stainless steel has demonstrated excellent tensile properties, and linear polarization measurements show equivalent corrosion resistance to the 15-5PH stainless. A first-generation value analysis model has also been distributed to manufacturing and repair communities for input.

TRANSITION: The technical approach of the project is designed to bring the alloy to the point of demonstration/validation testing for landing gear components. Based on its alloy development and chrome plating replacement experience, QuesTek will integrate the mechanistic modeling components used to design the alloy to streamline the process optimization and test program at significant reduced cost. In order to bring the technology to the demonstration/validation stage, it is necessary to produce a steel production specification and heat treatment specification to define the alloy, a steel properties performance database to support the technical case for the new steel, and detailed cost data to support the business case.

PROJECT SUMMARY

PROJECT TITLE & ID: Green Medium Caliber Munitions; PP-1237

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Roman Fednya; U.S. Army Armament Research, Development, and Engineering Center – Picatinny Arsenal, NJ

FY 2001 FUNDS: $117K

DESCRIPTION: In an effort to address medium caliber ammunition environmental problems in a systematic manner SERDP recommended that an umbrella program approach be utilized. In response, the US Army solicited the medium caliber ammunition technical community for membership on the Technical Advisory Committee (TAC) to better focus on the large number of diverse environmental issues. The TAC was formed in February 2001 and held a kickoff meeting on 28 March 2001 at TACOM-ARDEC, Picatinny Arsenal, NJ. Key agenda topics included SERDP program guidelines and identification of environmental problems by the using services and major contractors. Representatives from Academia also presented research activities supporting DoD. A green priority matrix identifying specific contaminants and quantities was addressed. The quantification of specific pollutants in the area of lead and toxic materials led to the development of this priority matrix based on the projected future multi-service medium caliber ammunition production acquisitions. The matrix assigned a high, medium, or low priority for the various contaminants and calibers involved.

BENEFIT: The Technical Advisory Committee's highest priority is the elimination or replacement of lead and toxic heavy metals. The TAC also provides specialized expertise, which can more effectively prioritize environmental needs and timelines to develop SONs. The nine focus areas include ignition systems, miniature detonators, miniature fuze electronics, propellants, tracers/incendiaries, detonators, paints, sealants/adhesives, and metal parts.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start. TAC has established and conducted two meetings which helped to identify and prioritize medium caliber ammunition environmental opportunities. SONs were prepared for the FY02 program in areas of percussion primers, electric detonators, and incendiaries resulting in SERDP publication.

TRANSITION: The TAC is scheduled to prioritize environmental needs and develop SONs in nine medium caliber ammunition focus areas through FY08.

PROJECT SUMMARY

PROJECT TITLE & ID: Improved Processing of Armor Ceramics for Reduced Emissions of VOC's and Greenhouse Gases; PP-1239 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Daniel Ashkin; Cercom, Inc. – Vista, CA

FY 2001 FUNDS: $100K

DESCRIPTION: The use of armor ceramics in the U.S. military forces is rapidly increasing. The manufacture of armor ceramics requires extensive use of energy, raw materials, processing, capital equipment and consumables. The environmental impact of processing these materials is considerable in terms of produced green house gases, the release of volatile organic compounds (VOC's), and the consumption of natural resources. Industry needs to identify which steps in the processing route can be modified to prevent pollution without affecting the function of the materials. The non-oxide ceramics have been shown to have the most promise for these applications and are the emphasis of this project.

The technical objective of this project is to use the principles of surface chemistry, ceramic processing and ballistic testing to develop new processing methods to eliminate the use of volatile organic components (VOC's) in manufacturing of non-oxide armor ceramics. These new processing techniques will be assessed in terms of chemistry, microstructure, mechanical properties and ballistic performance. The ballistic performance needs to be similar to that of conventionally processed material of the given composition.

BENEFIT: Eliminating or reducing the use of VOC's without affecting ballistic performance in the production of non-oxide ceramics would reduce the environmental impact of manufacturing these materials. The release of VOC's into atmosphere produces ozone, which is a significant environmental problem. The technology developed in this project would in addition ease the transition to forming methods that are near net-shape, which are of particular importance due to difficulties in machining armor ceramics.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start. This project started very late in FY 2001 and has no progress to report at this time.

TRANSITION: The project hopes to become an ESTCP program to the point of demonstration/validation testing of ceramic armor.

PROJECT SUMMARY

PROJECT TITLE & ID: Twin Screw Extruder Production of MTTP Decoy Flares - Pollution Prevention through Solvent Elimination; PP-1240

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Carol Campbell; Thiokol Propulsion – Brigham, Utah

FY 2001 FUNDS: $164K

DESCRIPTION: Magnesium, Teflon, and Viton or Hytemp (MTV or MTH) aircraft decoy flares continue to be important countermeasures to protect military helicopters and fixed-wing aircraft against heat-seeking missiles. Environmental and safety concerns are major drawbacks to the current processing technology for manufacturing these compositions. The current processes are batch processes that require transfers of large quantities of highly flammable solvents from one container to another. The solvents, acetone (VOC) and hexane (HAP), vaporize into the atmosphere, where they pose both environmental and safety hazards. Numerous events involving personnel injury and death have occurred. Risks of accidental ignitions are high, but eliminating these risks has been shown to be both difficult and expensive. In addition, open burning of scrap and demilitarization of items also present an environmental pollution problem.

The produced by a twin screw extrusion process which does not require the use of HAP or VOC's during manufacture. A continuous twin screw extruder (TSE) will be used to mix/extrude magnesium, Teflon, and polystyrene or ethylene-vinyl acetate thermoplastic binder (MTTP) into a decoy flare composition. The new material must meet or exceed current MTV or MTH countermeasure product performance specifications. Computer modeling, torque rheometry, and capillary rheometry will be used to establish the optimal extrusion formulation and process parameters. Strict process safety measures will be taken throughout the entire program to ensure the safe operation of this research and development effort.

BENEFIT: The proposed process will significantly reduce the air pollution, personnel health hazards, potential loss of life through solvent fires, and hazardous wastes associated with MTV or MTH countermeasure production. Cost savings would be realized by eliminating hexane and acetone from the manufacturing process. A preliminary cost analysis shows that 3.4 million dollars could be saved in countermeasure production over the next five years by eliminating these solvents. An additional cost savings would result from the improved process yield using the new technology.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start.

TRANSITION PLAN: The developed decoy flare formulation and process will be transitioned to the demonstration and validation phase based on the fully configured Army, Navy, and Air Force decoy flares. A pilot lot will be manufactured for this effort in accordance with the Army, Navy, and Air Force military specifications. This program focuses on corporation and open technology transfer between government and industry. Objective of this effort is to develop an environmentally acceptable aircraft decoy flare formulation.

PROJECT SUMMARY

PROJECT TITLE & ID: Novel Laser Ionization and Modeling for the Determination of Soot Mechanisms, PP-1241

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. William Anderson; Army Research Laboratory – Aberdeen Proving Ground, MD

FY 2001 FUNDS: $154K

DESCRIPTION: Soot emission during combustion is a consideration in nearly every system that uses fossil fuels as power source. There is heavy usage of combustion for propulsion by DoD, for example, in diesel and turbine engines. Besides the obvious health hazard of soot emission, soot formation in engines increases heat loading and can cause erosive engine damage, especially in turbine engines; and soot formation could increase target signature. Design engineers would greatly benefit from the availability of a good predictive model. Current models do not agree as well with experiment as one would desire. One possible reason is that ion chemistry may play an important role in the nucleation process (the early stage of soot formation when the growing entities are still molecular). Most current models do not consider ion nucleation because the majority of researchers feel the neutral species chemistry, i.e., radical - molecule reactions, is primarily responsible. However, there is a sizeable minority of researchers who believe ion chemistry is important. The issue of relative importance of ion versus radical mechanisms has not been conclusively settled despite over three decades of research.

Our approach will involve seeding of ions into flames and then following the resulting soot or soot precursor formation via diagnostic techniques such as mass spectroscopy. Creation of a reliable model will result in reduced design costs for diesel and turbine engines used by DoD.

BENEFIT: The SERDP product produced in this one-year project will have long-term benefits concerning the creation of a better model for the prediction of soot formation in combustion. The project expects to answer the long-standing issue of whether ion chemistry matters during the soot nucleation process. The lack of a proper understanding of the nucleation chemistry may be the fundamental reason why currently available models do not match experiment as well as desired, as presented in the SERDP statement of need and its associated documentation. Creation of a reliable model will result in reduced design costs for diesel and turbine engines used by DoD.

ACCOMPLISHMENTS: This is a FY 2001 Late New Start. The project started late in FY 2001 and has no progress to report at this date.

TRANSITION: The aim at the end of this project is to definitively answer whether an ion mechanism matters to soot formation. If an ion mechanism does matter, a second continuation proposal will be submitted for approval so a chemical kinetics model can be used by DOD, DOE, and industrial parties interested in diesel and engine turbine technology.

PROJECT SUMMARY

PROJECT TITLE & ID: Low Temperature Powder Coating; PP-1268

PRINCIPAL INVESTIGATOR & ORGANIZATION: Ms. Patricia C. Irwin; GE Corporate Research and Development – Schenectady, NY

FY 2002 FUNDS: $763K

DESCRIPTION: The DoD currently spends millions of dollars each year in procuring, using, and disposing of toxic and hazardous materials associated with solvent-bourne coatings for corrosion protection of fixed and mobile systems. The use of powder coatings eliminates more than 95% of the toxic and hazardous materials associated with the application of corrosion protection coatings. This SERDP program will provide a pollution-prevention-based solution to the continuing decline of the environment caused by solvent-based paint manufacturing processes as well as the elimination of chromate based primer systems.

In a 24 month program, a team comprised of DoD (NavAir and U.S. Air Force), DOE (Kansas City Plant), and large and small private industries (GE Corporate Research and Development and Crosslink Powder Coatings, Inc.) will identify and develop mission-critical powder coating resins that will eliminate volatile organic compounds, chromates and hazardous waste. Specifically, resins that are low-temperature curable (<230F), durable, corrosion inhibiting, and weather resistant will be developed. The new materials and processes will significantly reduce volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) when applied to the temperature-sensitive weapons system components. A full system approach consisting of three tasks will be employed in this program, as follows: (1) Formulate novel materials, (2) Develop powder coating materials, and (3) Develop field repair techniques.

BENEFIT: The development of new powder coating technology will have a major impact on the environment, and the manufacture and repair of all types of weapons systems. Elimination of VOCs by the use of low-temperature curable powder coatings will result in considerable cost savings due to the avoidance of hard controls and fines for compliance. The use of powder solvents will also not contribute any environmental damage to waste streams because powder coating systems are non-toxic and free of solvents.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: At the end of this project, one or more powder systems will be ready for demonstration and validation on full-size weapon systems and aircraft support structures by military partners.

PROJECT SUMMARY

PROJECT TITLE & ID: Reduction of Solid Waste Associated with Military Rations and Packaging; PP-1270

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Jo Ann Ratto; U.S. Army Natick Soldier Center – Natick, MA

FY 2002 FUNDS: $336K

DESCRIPTION: The nanocomposite packaging effort addresses the environmental need for solid waste reduction for military rations. The current packaging uses high barrier multi-layered materials containing foil as the barrier creating waste that is difficult to recycle and biodegrade. The objective of this project is to research and develop a cost effective, environmentally friendly,nanocomposite packaging material that will reduce the amount of solid waste associated with current and future military rations and packaging. The project will produce a novel nanocomposite packaging material that ultimately will eliminate miltary solid waste due to its recyclability and biodegradability. One promising class of nanoscale materials being investigated is that made from monmorillonite clays intercalated with organic polymers. Montmorillonites are silicate materials arranged in thin sheet-like layers. The ability to intercalate organic polymers in between the layers of the clay is what imparts the unique properties to the composites. Montmorillonite has been shown to reinforce plastics, increase barrier properties, improve dimensional stability, increase heat distortion temperature, and increase flame retardancy.

BENEFIT: If the nanocomposite packaging substitute is successful there will be a reduction in the plastic waste used for the current meal ready-to-eat (MRE). The current materials will be replaced with recyclable or biodegradable nanocomposites with improved properties and potential to reduce the cost of the military packaging.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION PLAN: Material converters will be consulted and involved in scaling up barrier film manufacturing from laboratory size to industrial size equipment. Natick technical teams, procurement agencies and industrial partners will participate in the down selection of materials, based on cost and producibility factors. New performance specifications for the incorporation of these advanced packaging materials into processed rations will be completed.

PROGRAM SUMMARY

PROJECT TITLE & ID: Low-Cost and High-Impact Environmental Solutions for Military Composite Structures; PP-1271

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. James Sands; U.S. Army Research Laboratory – Aberdeen Proving Grounds, MD

FY 2002 FUNDS: $460K

DESCRIPTION: Resin systems for liquid molding (LM) applications are being implemented with increasing frequency into designed structures for military composite platforms. The use of low-cost resins for LM, however, has a deleterious side effect. The viscosity reducing agent, typically styrene monomer, is a hazardous volatile organic compound that is freely emitted into the environment during mixing, processing, curing, and fielding of the composite structures. The key objective of this program is to formulate low-cost composite resin systems suitable for LM of composite components, including vinyl ester based composites. The program seeks to reformulate resin compositions used in LM fabrication to decrease VOC concentrations, resulting in reduced emissions throughout the composite life-cycle.

The technology being developed includes three approaches to mitigating VOC emissions by modifying existing baseline vinyl ester resin formulations. First, we seek to minimize emissions by decreasing the overall VOC concentrations in the resin blend. Second, we attempt to bind the VOCs into the matrix by increasing the reactivity at the composite interfaces, both surface and fiber interfaces. This last approach will involve substantial changes in the chemistry of the vinyl ester resins, which will require investigations into the reactivity relationships between the functional monomers in a multifunctional resin blend. A final push to reduce VOCs may incorporate combinations of the above technology approaches.

BENEFIT: The benefit of this program is to reduce VOC emissions across a broad range of composite applications for military platforms. A key to this program will be keeping costs of new resin formulations at reasonable levels to make the new alternatives competitive with current market resins, such as vinyl ester and polyester-based composites.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION PLAN: The resin formulations can be transitioned using key market players in the composites resin industry. The small resin manufacturers currently interested in supplying these technologies include UCB Radcure and Applied Poleramic, Inc. Our close relationships with these companies allow us to successfully develop materials for direct transition into military platforms.

PROGRAM SUMMARY

PROJECT TITLE & ID: Enhanced Electromagnetic Tagging for Embedded Tracking of Munitions and Ordnance during Future Remediation Efforts; PP-1272

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Keith Shubert; Battelle Memorial Institute – Columbus, OH

FY 2002 FUNDS: $481K

DESCRIPTION: To enable the DoD to conduct safe and environmentally benign training missions, significant advances in the detection of unexploded ordinances (UXO) must be pursued and implemented. Battelle Memorial Institute has proposed embedding RF tags on ordnance items to aid in locating UXO in the ground. The tag must be secured to the candidate ordnance item and be capable of surviving the delivery system. The tag must also survive ground impact and terrain penetration, as is the case with nonfunctioning (i.e., unexploded) ordnance items. The buried tag will be required to respond to and then signal the tag interrogation module when the detection system is brought nearby. The overall objective of this program is to: (1) Advance current RF tag capability to survive the operating conditions associated with munitions, (2) Provide information on the munitions location, and (3) Create technology compatible with operational and tactical deployment. The approach for this study is to determine reasonable operating objectives for current RF tag technology or other innovative tagging devises and evaluate tag technology against known constraints or newly established and prioritized operational criteria. Several candidate Tag/Interrogator systems will be systematically explored and tested and a recommendation will be made to the Government at the end of the contract.

BENEFIT: The immediate benefit of the successful execution of this project will be the demonstration of the proof-of-principle of successful detection and location of unexploded ordnance and munition items that have pre-embedded RF tags. The additional required materials and processes will be shown to be comparatively inexpensive. The resulting long-term benefit will significantly decreased costs of range remediation because of the much higher probability of detecting unexploded ordnance with many fewer false alarms.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION PLAN: From the beginning of the project, every effort will be made to ensure that the results and findings of this effort are evaluated in the constraints of eventual DoD implementation. To that end, the project team includes key individuals from Navy, Army, and Air Force with munitions and ordnance management responsibilities. The project will also be focused on the next step in the development process, which will be the implementation of a demonstration system that will allow more realistic evaluation by the DoD munitions and ordnance community and the appropriate environmental agencies.

PROGRAM SUMMARY

PROJECT TITLE & ID: Multispectral Munitions Locating System; PP-1273

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Al Quintana; Naval Air Warfare Center Weapons Division – China Lake, CA

FY 2002 FUNDS: $135K

DESCRIPTION: Due to the environmental and safety concerns the ability to accurately identify and locate munitions and impact areas has become a major concern on military land ranges. The optical augmentation concept used for the multispectral locating system comes directly from comments by Explosive Ordinance Disposal (EOD) personnel responsible for clearing test ranges after operations. The concept uses a simple retro reflective material applied to the munition to provide ample augmentation when properly illuminated and viewed with a matched detector. Optical augmentation will make the munition very conspicuous even when partially obscured. When used in conjunction with a miniature RF tag, the type and condition of the munition involved can be determined.

The objective of this effort is to develop optical augmentation and/or a long-range miniature radio frequency (RF) tag that can be used to reliably locate unexploded munitions on the surface of a land test range. The technology will also be able to (1) identify optimum sensors for the task, (2) demonstrate optical augmentation, and to (3) evaluate whether the concepts can be effective in reducing the effort and cost of removing UXO.

BENEFIT: The system will facilitate the timely removal of hazardous UXO material so that range personnel can enter and reuse an area safely. Long term safety hazards are reduced by reducing the amount of UXO in a test range not accounted for. There is also the need to remove hazardous UXO to prevent the materials long term potential to enter the ecosystem. Pollution prevention is served by removing munitions that may over time leach out hazardous material.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION PLAN: This effort is proposed as a concept demonstration effort. Field tests performed with the optical augmentation prototypes will demonstrate the observable contrast of BLU-97 facsimiles in a desert environment. If the field tests and evaluations by EOD personnel indicate that the scheme is desirable, further development of an optical augmentation scheme will be warranted. Based on favorable results and comments from these teams we will solicit a SERDP development task to refine the concepts and move them forward for further development and utilization on test ranges.

PROGRAM SUMMARY

PROJECT TITLE & ID: Non-Leaching, Benign, Fouling Control, Multilayer Polymer Coatings for Marine Applications; PP-1274 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Christopher Ober; Cornell University – Ithaca, NY

FY 2002 FUNDS: $100K

DESCRIPTION: To date, several commercial fouling release (FR) coating systems are on the market, all based on silicone technology, yet none meet all of the desired performance characteristics. Many lack the toughness required to stand up to the rigorous physical demands of the marine environment, do not sufficiently and consistently self-clean, or, due to polymer re-structuring or other degradation pathways, lose many of the desirable surface properties with time and exposure to the marine environment. The objective of the proposed project is to develop non-toxic, copper-free, environmentally benign antifouling polymer coatings produced by blending styrene-ethylene/butylene-styrene (SEBS) thermoplastic elastomers with surface-active block copolymers (SABC). The project intends to demonstrate the proof-of-principle of these multilayer systems and, with understanding of the key problems involved, develop improved systems for fouling release that mitigate the use of toxic organocopper antifoulants. This will be accomplished by determining whether polar or non-polar SABC offer the best materials for non-fouling coatings and optimizing these materials, and designing and synthesizing large enough quantities of optimized SABC to provide samples for long term testing.

BENEFIT: The new copper free coating will be designed to exceed the current performance of fouling release silicone coatings. The proof-of-principle will be demonstrated through testing these multilayer systems and, with understanding of the key problems involved, developed with improved systems for fouling release that mitigate the use of toxic organocopper antifoulants.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION PLAN: A final report will be issued which provides an objective assessment of the viability of using the copper free fouling release coating system created in this project. Once the goal for establishing the success of the strategies for a non-fouling coating in a marine environment as outlined in the proposal is achieved, testing in natural and simulated conditions is envisioned.

PROGRAM SUMMARY

PROJECT TITLE & ID: Environmentally Acceptable Alternatives for Non Destructive Inspection with Fluorescent Penetrant Dyes; PP-1275 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Bradley Grunden; METSS Corporation – Westerville, OH

FY 2002 FUNDS: $100K

DESCRIPTION: The DoD currently uses synthetic and petroleum based oils as carrier fluids for fluorescent dye penetrants (FDP) used during the nondestructive inspection (NDI) of metal parts (during manufacture and in-service). Current DoD handling and disposal costs associated with these processes are estimated to be approximately $4 million per year. The primary objective of this project is to develop and transition environmentally acceptable fluorescent dye penetrants for use in existing nondestructive inspection techniques and reduce the time required to perform NDI via FDP techniques.

Based upon the critical performance parameters of existing fluorescent dye penetrant materials, METSS will formulate a series of alternative carrier fluids and cleaners for fluorescent dye penetrant materials and construct a design matrix from which the viability of these FDP replacement formulations can be evaluated with respect to performance, environmental impact, and cost. The general physical and chemical requirements of the candidate materials will drive the initial materials selection efforts.

BENEFIT: The products developed under the proposed program will not only be non-toxic, safe to use, and environmentally friendly, but will also be cost effective. By emphasizing the development of direct replacement fluid technologies, METSS efforts will have a significant and immediate impact on the reduction of waste streams generated by existing FDP techniques, while at the same time making it possible to use existing systems in a manner that is safer to personnel and the environment

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION PLAN: Magnaflux's support of the proposed efforts will ensure the products developed are viable replacement materials for FDP NDI techniques by providing industry specific expertise and by supporting meaningful and practical evaluation of the candidate replacement fluids. Magnaflux will also provide a commercialization vehicle for the technologies developed under the proposed program, thereby ensuring technology transition and commercial availability.

PROGRAM SUMMARY

PROJECT TITLE & ID: Safe and Environmentally-Acceptable Sol-Gel-Derived Pyrophoric Pyrotechnics; PP-1276

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Randy Simpson; Lawrence Livermore National Laboratory – Livermore, CA

FY 2002 FUNDS: $100K

DESCRIPTION: The current manufacturing process and materials used to make pyrophoric decoys introduces a considerably toxic component to the waste stream. The "sol-gel" methodology intends to produce nanostructured energetic materials (i.e., pyrotechnics) while minimizing or eliminating the health and environmental hazards associated with their current fabrication. This sol-gel approach for preparing pyrotechnic formulations involves a fundamental change in the conventional manufacturing and fabrication processes of energetic materials. It is believed that low temperature reduction of high surface area porous sol-gel-derived iron(III)oxide with molecular hydrogen will result in the formation of porous pyrophoric iron metal, suitable for use in pyrophoric decoy flares. The proposed effort will demonstrate that processing and preparation.

BENEFIT: The project intends to demonstrate that processing and preparation with environmentally acceptable media under neutral conditions can replace the current process used in pyrophoric flare manufacturing, while producing a suitable pyrotechnic dispersion when deployed.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION PLAN: The Naval Surface Warfare Center, Crane, IN, will test and evaluate the materials and will provide the guidance for product development and provide an interface with the production facilities that would ultimately manufacture the sol-gel. The focus of this work will be on pyrotechnic needs for existing and anticipated infrared countermeasures. Sol-gels can be used to achieve this demand.

PROGRAM SUMMARY

PROJECT TITLE & ID: Control of Biofouling Using Biodegradable Natural Products; PP-1277 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kathleen Fallis; Naval Air Warfare Center Weapons Division – China Lake, CA

FY 2002 FUNDS: $100K

DESCRIPTION: Biological fouling of seawater piping and heat exchange equipment impacts nearly all oceangoing vessels, both commercial and military, resulting in poor performance and excessive maintenance costs. The current approach used by the U.S. Navy for the control of biofouling is well above Clean Water Act and Uniform National Discharge Standards. In order to comply with these requirements, and those that may be imposed in the future, it has become necessary to look to alternative methods for the prevention or control of biofouling. The objective of this research is to investigate the use of biodegradable, naturally occurring substances as additives to eliminate or inhibit the biological growth present in shipboard heat exchange equipment. Three candidate plant extracts will be examined for their effectiveness in preventing biofouling of designated metallic materials in seawater systems. The testing of these additives for use in shipboard heat exchange systems will be performed, taking into account the many variables. Testing will be undertaken to evaluate biocidal performance under a wide range of conditions in order to obtain realistic results.

BENEFIT: The results from testing will indicate the potential for the use of plant extracts as biofouling inhibitors. Substantial cost savings may be realized from the reduced manpower required to maintain shipboard heat exchange and plumbing systems. Performance of these systems will also be positively impacted if biofouling is minimized. In addition, significant environmental impacts may be realized if these substances are to be suitable as replacements for chlorination.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION PLAN: Based on a successful laboratory/field test regimen, the results of this study will be evaluated, and if the concept deemed feasible for further development, a proposal dealing with such will be submitted to SERDP for additional funding.

PROGRAM SUMMARY

PROJECT TITLE & ID: Pulsed Acoustic Sparker Bio-Fouling Control in Heat Transfer Equipment; PP-1279 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Raymond Schaefer; Phoenix Science & Technology, Inc. – North Chelmsford, MA

FY 2002 FUNDS: $100K

DESCRIPTION: Biological fouling is a problem in U.S. Navy ships and submarines (heat exchangers, condensers and seawater piping systems) and for the U.S. Army Corps of Engineers (dams, locks, and hydroelectric plants). Biofouling adversely effects system performance by decreasing heat transfer and blocking the flow of water. Chlorination is an effective antibiofouler, but has negative environmental impacts and does not meet federal and state regulations. The project technical objective is to demonstrate the feasibility of using pressure pulses from sparker acoustic sources to replace chlorine as the major means for controlling biofouling. The proposed concept is to use short high peaked pressure pulses generated by a sparker acoustic source to prevent biological fouling inside of pipes of heat exchanger equipment. The sparker is controlled remotely powered through cables and does not touch the pipe, so that it can be used with any pipe material.

BENEFIT: A successful program will show feasibility of a sparker biocontrol concept by demonstrating microfouling control of slime in a single pipe representing a typical pipe in a heat exchanger. The results will provide the basis for further development in which the sparker will be used to control biofouling of practical heat exchangers and heat transfer equipment in general.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION PLAN: Based on a successful laboratory/field test regimen, the results of this study will be evaluated, and if the concept deemed feasible for further development, a proposal dealing with such will be submitted to SERDP for additional funding.

PROGRAM SUMMARY

PROJECT TITLE & ID: Elimination of Chlorine Containing Oxidizers from Pyrotechnic Flare Compositions; PP-1280

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Shortridge; Naval Surface Warfare Center – Crane Division, IN

FY 2002 FUNDS: $203K

DESCRIPTION: This research effort will identify feasible approaches for reformulating a variety of pyrotechnic compositions to reduce or eliminate toxic reactants. Current flare compositions use inorganic perchlorate compounds that react to form the highly objectionable hydrogen chloride (HCl) combustion product. The objective of this research is to formulate and test improved pyrotechnic compositions, which contain high-energy metallic fuels and alloys and non-chlorine-containing inorganic oxidizers, instead of the currently used chlorine-containing oxidizers. Because the replacement nitrate or oxide oxidizers are less reactive than those that contain chlorine, high-energy fuels will be used to make up for the loss in energy. These high-energy fuels will be using Mechanical Alloying (MA) technology. This novel approach allows for the creation of fuel particles which combust to generate metal oxides, ultrafine reactive metal droplets, and the hot combustion gases needed to disperse them. Compositions meeting acceptance criteria will be scaled up to prototype scale, and performance tested under static conditions, as well as under simulated flight conditions.

BENEFIT: The new compositions will produce equal or superior emission intensities in the visible and/or infrared regions, as appropriate to the pyrotechnic application. They will also eliminate or reduce the quantity of HCl generated, reducing the burden of HCl pollutants on the environment.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION PLAN: Potential sponsors for the transition of this project include NAVAIR (PMA-272), ONR, JTCG/AS, and Army AIRCMM and/or Air Force Mixed Expendables follow-on programs, all of whom are interested in improving spectrally balanced flares. Also, NAVSEA PM4, who is funding a related project to design and test environmentally acceptable colored signal compositions, and ESTCP are potential sponsors.

APPENDIX E
UXO Project Summaries

PROJECT SUMMARY

PROJECT TITLE & ID: Low-Frequency Ultra-Wideband Boom Synthetic Aperture Radar (Boom-SAR) for Remote Detection of Unexploded Ordnance (UXO); UX-1070

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Marc Ressler; Army Research Laboratory – Adelphi, MD

FY 2001 COMPLETED PROJECT

DESCRIPTION: Currently, methods for detecting unexploded ordnance (UXO) involve laborious ground surveys that are slow, dangerous, and impractical for dealing with vast UXO-contaminated lands. Synthetic Aperture Radar (SAR) is an advanced technology that offers significant potential for quickly and safely detecting UXO. The Army Research Laboratory (ARL) BoomSAR is a fully polarimetric research quality radar that operates across a 1-GHz-wide band, from 25 MHZ to 1 GHz. This bandwidth contains low frequencies needed for ground penetration, while maintaining higher-frequency coverage for high-resolution imagery. The ultra-wide bandwidth provides measured range resolution of 0.15 m; the aperture length provides cross-range resolution of 0.15 m. The radar is mounted on a boom-lift that can operate at heights of 5 to 45 m while moving at 1 km per hour, allowing the radar to operate in a strip-map SAR mode. The goals of this project were: (1) Determine the applicability of low-frequency ultra-wideband (UWB) SAR for detecting and discriminating surface and subsurface UXO; (2) Refine and validate electromagnetic models that can be used to extrapolate UWB SAR performance to other environmental conditions (soils); and (3) Develop detection algorithms for separating UXO from clutter.

BENEFIT: This effort will help to determine the utility of SAR for surveying large regions and detecting and discriminating various surface and subsurface UXO. This technology has the potential to achieve rapid survey speeds/coverage rates while allowing safe standoff distances during operation. ARL's BoomSAR will be used to collect high-quality precision data to support phenomenological investigations of electromagnetic wave propagation through dielectric media. These investigations, in turn, will support the development of algorithms for target detection. Data was collected at two UXO test sites that have been seeded with a comprehensive variety of inert UXO.

ACCOMPLISHMENTS: Models, measurements, and analysis are converging to provide valuable insight on the efficacy of UWB SAR for remote sensing of likely UXO-contaminated areas. Correlation between the model predictions and field-measured target signatures establish credibility of the models. Models are being used to assess amplitude, frequency, and angle dependent scattering behavior. The models demonstrate that usable signal levels exist for many types of surface and near-surface UXO. Clutter and soil loss are the critical factors of concern, and the models lag in this domain. Anecdotal measurements indicate that there are considerable differences in clutter competition and loss, dependent upon the specific geophysics of the site. Analysis of Eglin and Yuma data continued, and a measure of clutter response has been developed. A specific method for providing an overarching assessment of UWB SAR utility has been outlined. Applicability assessments for particular sites will require detailed site knowledge. Testing of new antennas is underway; these antennas provide inherently broader angle response, better high-frequency response, and much better polarimetric response.

TRANSITION: The BoomSAR data collected from the Yuma and Eglin tests has been archived for the use of other researchers. In deed, some of this data has already been used by other SERDP-funded projects. The utility assessment will help guide future investments in SAR technology.

PROJECT SUMMARY

PROJECT TITLE & ID: Innovative Seismic System for Buried Unexploded Ordnance Detection and Classification; UX-1091

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Peter Krumhansl; BBN Systems and Technologies – Cambridge, MA

FY 2001 COMPLETED PROJECT

DESCRIPTION: The objective of this effort is to investigate and develop a new Seismic Ordnance Detection System (SODS), which has the potential to improve the discrimination of unexploded ordnance (UXO) from clutter and thus reduce the number of excavations required during cleanup. The new seismic sensor will sense the mechanical properties of buried objects rather than their magnetic or electrical properties. The SODS system will operate in a manner similar to an active sonar system, with a mobile seismic array which sends broadband vibrational energy into the ground. These waves, when they encounter an object with anomalous mechanical properties, cause the object to rotate, translate, and to "ring," scattering energy back to the surface. These echoes will be received by an array of geophones and digitally recorded. The received signals are focused to locate the objects and to analyze the characteristic echo from the object. These characteristic echoes, when used in conjunction with the magnetic and electrical response, may be used to differentiate UXO from inert objects.

The technical approach for the investigation and development of the SODS consisted of: (1) Performance of an initial feasibility study to analyze the practicality of seismic UXO detection using short wavelength shear waves; (2) Development of a proof-of-concept SODS for testing; and (3) Evaluation of the proof-of-concept SODS in controlled testing. The system simulation of SODS was based on computer modeling and field measurements of seismic wave propagation and noise. The second phase utilized seismic sources and receivers that provide greater bandwidth, increased source level, and better earth coupling than are commercially available, while engineering a practical mobile array of seismic transducers that can be used to efficiently collect seismic data. The third phase included refining of the proof-of-concept system through diagnostic tests and analyzing detections of UXO, culminating in an initial evaluation of SODS in multi-sensor tests and an analysis of false alarm reduction using the seismic data in a sensor fusion process.

BENEFIT: The project provided a proof-of-concept: (1) SODS that has been tested and verified for the collection of field data; (2) SODS data for UXO targets acquired in real world conditions; and (3) an assessment of the applicability of seismic techniques to UXO detection.

ACCOMPLISHMENTS: Responses from the field testing of SODS were analyzed. A detectable and fairly repeatable response was observed for shallow-buried 155 mm shells. The response was found to be complex and fake targets were observed in the data. The data was used to improve understanding of seismic wave propagation ins hallow soil environments. Problems with reverberation, near surface variability, and receiver coupling were identifiable. Potential improvements in hardware and processing have been proposed.

TRANSITION: The digital seismic data from the field tests of the Proof of Concept Seismic Ordnance Detection System was prepared for other researchers to use. In addition, a comprehensive description of the project was written in the final report, focusing on the latest field test results in 2000, the analysis and the scientific lessons learned.

PROJECT SUMMARY

PROJECT TITLE & ID: Processing Techniques for Discrimination between Buried Unexploded Ordnance and Clutter Using Multisensor Array Data; UX-1121

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Bell; AETC, Inc. – Arlington, VA

FY 2001 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to develop a reliable technique for discriminating between buried UXO and clutter using multisensor electromagnetic induction sensor array data. The effort builds on existing research which exploits differences in shape between ordnance and clutter to include the effects of other distinctive properties of ordnance items (fuze bodies, driving bands, fin assemblies, etc.).

Specifically, the project performed tests on Electromagnetic induction data taken in the less than 100 kHz domain. The effort developed: (1) Models for the ordnance signature and its constituent parts; (2) Procedures for determining target characteristics from multisensor data using the signature models; and (3) Decision rules for discriminating between buried UXO and clutter.

BENEFIT: The project provides effective tools for discriminating between buried unexploded ordnance (UXO) and clutter in the context of environmental cleanup. In spite of the recent advances in UXO detection performance, false alarms due to clutter (signals incorrectly diagnosed as having been caused by UXO) remain a serious problem. With traditional survey methods, the Army Corps of Engineers finds that 85-95% of all detected targets are not UXO. Since the cost of identifying and disposing of UXO in the United States using current technologies is estimated to range up to $500 billion, increases in performance efficiency due to reduced false alarm rates can result in substantial cost savings. The products of this research are primarily processing algorithms and procedures for using existing sensor technology within the less than 100 KHz domain.

ACCOMPLISHMENTS: In FY01, the project focused on developing data processing algorithms for UXO/clutter discrimination. The approach is based on defining characteristic regions in parameter space which correspond to targets of interest. Given a set of field data, parameters are derived using an electromagnetic induction (EMI) response model, and then the parameters are compared again with the pre-defined characteristic regions to indicate UXO or clutter. The approach to UXO/clutter discrimination is based on decision rules applied to target-specific parameters derived from EMI survey data. Discrimination performance is governed by the degree to which parameter regions for UXO and clutter overlap. It is therefore desirable to design the EMI response model so that derived parameters from a given target are as consistent as possible over all positions (depths) and orientations of that target. A significant amount of variability in derived parameter values is related to non-dipole effects, caused by non-uniformity of the excitation field within the body of the target. These effects are most prominent for larger UXO like the 155mm projectile, because greater non-uniformity is encountered with greater volume. A simple algebraic correction was developed to help remove these errors. The correction factor is based on simple terms that reflect the degree of non-uniformity of the primary field, such as the ratio of the maximum field strength inside the target divided by the field strength at the center of the target. A paper was presented at the UXO/Countermine Forum covering aspects of this project.

TRANSITION: Primary products are the ability to optimize EMI sensor array configuration and development of effective processing algorithms for EMI data. These may be directly transitioned to modify the Multi-Sensor Towed Array Detection System (MTADS) platform and data analysis system. The research effort entails direct involvement with the user community.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Discrimination by Mid-Frequency Electromagnetic Induction; UX-1122

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kevin O'Neill; U.S. Army Corps of Engineers Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory – Hanover, NH

FY 2001 COMPLETED PROJECT

DESCRIPTION: This project performed basic research on sensor development, sensor utility, and signature possibilities in the uncharted 25 kHz – 300 kHz Medium Frequency - Electromagnetic Induction (MF-EMI) electromagnetic frequency band, for induction sensing of buried Unexploded Ordnance (UXO). The goal was to provide enhanced discrimination of ordnance from non-ordnance, and thereby reduce false alarm rates during field surveying. This was accomplished by innovative instrumentation development in the MF-EMI band, in tandem with new modeling work.

Technical objectives for this project included: (1) Perform lab measurements of soil electrical properties, including seasonal effects, for samples relevant to UXO sites in order to quantify expected subsurface signal loss rates; (2) Extend and verify suite of computer programs to achieve rigorous 3-D solution of the physics of response by non-idealized UXO and non-UXO targets in realistic environments in this frequency range; (3) Produce high fidelity simulations in time, space, and frequency domains of the response by a wide range of specific UXO morphologies and dispositions, and by common non-UXO targets (fragment clusters, tin cans, open shapes, etc.) in realistic environments; (4) Obtain measured induction responses for array of UXO and non-UXO targets, using technology to be developed and exploiting existing data bases where possible; and (5) Use all of the above to identify distinctive UXO signature behaviors, and their discernability relative to the environment, for combination with those being obtained in frequency ranges both above and below 25 kHz - 300 kHz.

BENEFIT: This work builds directly on recent progress in innovative EMI signature identification in the lower frequency EMI range (100 Hz – 25 kHz) and thereby amplifies its impact. As basic research it will not provide immediate answers, but is directed towards aiding in: (1) Substantial reduction of the false alarm rate in UXO field surveying; (2) Cheaper remediation of UXO hazard sites; (3) Faster and safer surveying of potential hazard sites; and (4) Computational and modeling tool development for wide range of related electromagnetic applications.

ACCOMPLISHMENTS: All fundamental numerical codes have been completed and tested. These codes include a general axisymmetric code and a 3-D code. Both were designed to operate reasonably well over all frequencies for material homogeneous objects as well as bodies with sections made of different metals. In addition, another specialized "thin skin depth" code has been completed and tested. It is designed to handle optimally the problematical domain in which magnetic field penetration of the target is slight but cannot be ignored (a common occurrence over much of the EMI spectrum but particularly in the higher frequencies). These codes were integrated into a single package.

Numerical results indicated the importance of basic elongated shapes; that is, details of the shapes are evidently less important than the general shape (e.g., aspect ratio), even at highest frequencies. This has thrown focus on solutions for fundamental elongated shapes, i.e., spheroids. A special treatment of the analytical solution for the case of axial excitation was brought to fruition, using only scalar prolate spheroidal wave functions for the heart of the solution, and simpler associated Legendre functions in the higher frequency limits, applicable in this project. Treatment of the more general case was also pushed forward (i.e., including arbitrary excitation and target orientation, with special treatment of both high frequency and high magnetic permeability cases). Results present a limiting form of the solution that should be widely applicable to steel or ferrous metal elongated targets, at both high and low frequencies. This solution should be invaluable for inversion calculations. Measurements using the network analyzer were achieved with the system at ultra low frequencies, showing significant signal activity below 30 Hz. That is, not merely significant signal amplitudes were encountered, but significant signal features were observed for larger ordnance (e.g., peak in quadrature component).

TRANSITION: The project will transition knowledge to a FY02 New Start project, UXO Discrimination in Cases with Overlapping Signatures (UX-1282). Original research results have been published in peer-reviewed journals. Laboratory data will be archived for the use of other researchers.

PROJECT SUMMARY

PROJECT TITLE & ID: Statistical Signal Processing with Physics-Based Models: Multi-Sensor UXO Detection and Identification; UX-1123

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Leslie M. Collins; Duke University – Durham, NC

FY 2001 COMPLETED PROJECT

DESCRIPTION: Several sensor modalities are currently being explored for the detection and identification of surface and buried unexploded ordnance (UXO). These include electromagnetic induction (EMI), magnetometers, radar, and seismic sensors. These sensors experience little difficulty detecting the UXO, thus detection does not create the bottleneck that results in the high cost of remediating sites. The primary contributor to the costs and time associated with remediating a UXO contaminated site is the high false-alarm rate associated with each of the sensors when operated individually.

In this project, the team investigated the phenomenological aspects of the UXO detection, location, and discrimination problem using EMI, radar, seismic, and magnetometer sensors. The technical approach employed synergistic research activities in modeling, signal processing, and sensor fusion. The researchers performed phenomenological modeling of wave propagation and scattering for ultra-wideband (UWB) radar, seismic, and EMI sensors. The phenomenological studies were performed in collaboration with SERDP-supported sensor-development programs underway in these areas (at NRL, ARL, and BBN). The previously developed models were extended to allow arbitrary numbers of soil layers, arbitrary target shape and orientation, and to accurately account for all interactions. The use of these models quantified the target types, depths, and soil conditions for which radar is an appropriate sensor. These models of the wave physics, coupled with models of target, clutter, and environmental uncertainties, were incorporated into a statistical signal processing framework, thus novel, state-of-the-art optimal detection and identification algorithms will be developed for each sensor. Bayesian algorithms, which provide the optimal solution to detection and identification problems, were investigated along with an algorithm based on a Hidden Markov Model formulation which is specifically suited for classification using data from multiple aspect angles. Finally, the researchers developed sensor-fusion techniques that simultaneously exploit the richness and diversity of the phenomenology underlying multiple sensor modalities. Again, both Bayesian and Hidden Markov Model algorithms were investigated. In all cases, the algorithms were tested on data collected using sensor systems also under SERDP support, such as the BBN seismic sensor, Naval Research Laboratory (NRL)'s Multi-Sensor Towed Array Detection System (MTADS), the Army Research Laboratory (ARL) Boom-SAR, and Geophex's GEM-3 EMI sensor.

BENEFIT: The goal of this project is to develop algorithms that substantially reduce false alarm rates associated with individual sensors, and that optimally combine information across sensors to further reduce the false alarm rate. Such reductions would dramatically decrease the time required to remediate Formerly Used Defense Sites (FUDS) and Base Realignment And Closure (BRAC) sites, thus decreasing the associated costs. One of the principal reasons for organizing cooperative agreements with ARL, NRL, and BBN is to assure the models and algorithms developed under the proposed research are transitioned as quickly as possible to the users in the field. It is felt that the collaborative relations will allow the researchers to tailor project developments such that they are of use to practical systems. Moreover, these organizations, which are responsible for hardware design and measurement campaigns, will gain insight from the phenomenological models to assure that the systems are designed and deployed in the most salutary fashion.

ACCOMPLISHMENTS: The modeling work has focused on three sensors: magnetometer, time- and frequency-domain EMI, and Boom-SAR. A simple dipole model for magnetometer data was applied to field data and was successfully used to estimate target depth. Additional parameters estimated with the model have also shown promise as target discriminants. A full MoM model for predicting the fields recorded by EMI sensors was developed as well as a simpler model that assumes that the induced magnetic fields can be characterized by a dipole. A simple model for cylinders and rings has also been developed. Its ability to reproduce cylinder and UXO data has been validated, and the model has been disseminated to the community. For the Boom-SAR, a multi-level fast-multipole algorithm was developed for modeling radar scattering. The model results in considerable computational savings and has been compared favorably to measured radar data. One of the signal processing efforts focused on applying statistical techniques to field data measured during the JPG-IV experiment. This work resulted in performance improvements over those obtained by the various vendors. In particular, in a cross validation study, a statistical technique outperformed both an expert analyst and the NRL neural network on the JPG-IV data set. This work has shown the utility of fusing magnetometer and EMI data. The multi-level fast-multipole (MLFMA)algorithm was used to develop a hidden Markov model for processing SAR data, and the results appear promising. A HMM was analyzed for EMI data, although it appears from initial results that a Bayesian approach performs better. Several small data collection efforts were performed to support the algorithm development efforts. The fundamental limitations of estimating decaying exponential parameters from EMI data in support of the modeling activity described above was also considered.

TRANSITION: The project intends to transition cooperative developments. These include organized cooperative agreements with ARL, NRL, and BBN. The project will transition knowledge to a SERDP-funded FY 2002 New Start project, Signal Processing and Modeling for UXO Detection and Discrimination in Highly Contaminated Sites (UX-1281).

PROJECT SUMMARY

PROJECT TITLE & ID: Statistical Methods and Tools for UXO Characterization; UX-1199

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. Brent Pulsipher; Pacific Northwest National Laboratory – Richland, WA

FY 2002 FUNDS: $309K

DESCRIPTION: Many Formerly-Used Defense Sites (FUDS) are slated for clean up and transfer to the public for other uses. The risks associated with Unexploded Ordnance (UXO) in soils at the sites are a significant concern. Risks must be managed to acceptable levels commensurate with hazardous clean-up activities and intended future use. There are two types of risks that must be considered: (1) Risk of leaving unidentified UXO that could be discovered after clean up has been completed, and (2) Risk of spending scarce resources on characterization with a non-optimal characterization scheme or when there is no real threat present.

This research team proposes a program that will evaluate and develop statistical methods and tools that can be used to develop characterization and verification plans and data evaluation schemes that will appropriately account for these two sources of errors. Significant research on UXO detection system performance has been conducted and continues. Pertinent estimates of probabilities of detection and false positive error rates will be extracted from these programs. Although this proposed activity will incorporate estimates of measurement error, the focus will be on the statistical sampling methodology, not the measurement performance. The performance of acceptable methods relative to the two risks (cost and hazard) will be evaluated. Once the methodologies are selected, statistical algorithms that are easy to apply or lend themselves to software implementation will be developed. Finally, prototype tools will be developed and demonstrated using existing data or as part of a characterization scheme on a particular UXO site.

BENEFIT: It is envisioned that the statistical methods developed will provide a mechanism for developing sampling schemes that will result in an acceptable level of confidence that UXO is not a percent on certain portions of a site. The methods will allow the stakeholders to analyze the tradeoffs between sampling requirements and risk of incorrect decisions. A statistically based sampling approach could avoid significant costs of characterization. Specific payoffs will be the availability of methods and tools in the form of technical reports, publications, software, and presentations.

ACCOMPLISHMENTS: During FY01 emphasis was placed on exploring and developing statistical sampling methods that would be relevant to typical UXO characterization applications. The appropriate approach to sampling depends on the Conceptual Site Model (CSM) and the phase of characterization. Sampling and statistical analysis methods are needed for the generalized CSM characteristics.

In FY01, approaches were explored to determine the optimal sampling schemes for confidently detecting a target area of a specified size and shape and to define the boundary of a potential target area. These approaches are based on the Data Quality Objectives process. Methods were also explored for quantitatively determining the confidence that no UXO are present at a site when no UXO are found in a given partial survey. These methods incorporate Bayesian techniques that account for prior belief or corroborating evidence.

Currently, some of the methods have been programmed within Visual Sample Plan, a software package that helps the user determine the number and location of samples/swaths required to adequately protect against decision errors. For the current implementation, the user inputs DQOs and information on the desired probability of traversing a target zone, the size and elliptical shape of the target zone of concern, the width of the swaths/transects, the swath pattern (parallel swaths, rectangular/square grid), and the swath orientation.

Then VSP determines the required transect spacing and placement to have at least the specified chance of traversing a target zone of specified size and shape if it exists somewhere on the site.

Adaptive sampling methods have also been explored for bounding a target zone once it is detected. More study is required before determining an optimal sampling approach when determining a boundary is the primary objective. Finally, compliance sampling methods have been derived to support cases when no UXO have been found on site.

TRANSITION: The statistical methods and prototype tools developed under this project will be applicable to many users at DoD facilities where UXO is a concern. Statistical methodologies will be demonstrated using existing or simulated data or in conjunction with one or more actual UXO site characterization activities. Final validation will require a full scale demonstration at a UXO-contaminated site. Working with UXO site characterization managers and personnel to apply the methods will be an excellent opportunity for transitioning the expertise developed. Development of a prototype software tool incorporated into the EPA-sponsored visual sample plan software suite and will greatly enhance the transition of the methodologies to practice.

PROJECT SUMMARY

PROJECT TITLE & ID: Bayesian Approach to UXO Site Characterization with Incorporation of Geophysical Information; UX-1200

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Sean McKenna; Sandia National Laboratories – Albuquerque, NM

FY 2002 FUNDS: $280K

DESCRIPTION: The occurrence of unexploded ordnance (UXO) on DoD controlled sites is of critical importance as these sites are prepared for return to the public sector. Efficient characterization and remediation of UXO at these sites is necessary. The current practice of statistical characterization of UXO sites is based on classical statistical approaches derived from assuming the occurrence of UXO is the result of a Bernoulli process. This assumption does not allow for spatial correlation of the UXO density, and it is difficult to incorporate ancillary information provided by geophysical techniques and archival site records in an objective manner.

This effort describes an approach for the characterization of the intensity (density) of UXO across a site that can make use of archival site records and geophysical information. A doubly stochastic Poisson process defines the occurrence of UXO. The spatially varying intensity of this Poisson process can be estimated with spatial statistical algorithms. The result of this description is that the determination of the precise locations of any individual UXO in the subsurface will require sampling at that specific location. However, determination of the variable UXO intensity across a site does not require exhaustive sampling and can make use of less precise, or subjective information through a Bayesian updating approach.

Bayesian updating produces a map of the site displaying the probability of exceeding a specified clean-up goal. This probability of exceedence is the probability of failing to meet the clean-up criteria. A data worth framework is applied to the characterization/remediation alternatives being considered to optimize the sampling locations and determine the number of samples that lead to the lowest total project cost. This approach will be developed using an exhaustively known data set. The approach will be validated and compared to current UXO site characterization guidelines on a separate data set.

BENEFIT: This project will provide a new, validated, UXO characterization protocol that can be applied to DoD sites. This protocol will significantly improve currently available techniques used to characterize UXO sites by incorporating prior information through a Bayesian approach, by using geostatistical techniques to update that prior information, and by optimizing the characterization using a data worth approach. This protocol is designed to take advantage of the recent investment in detailed geophysical survey technology that has been made by SERDP and other branches of DoD. The overall benefit of this project will be to provide a more efficient and defensible protocol for the characterization of UXO sites.

ACCOMPLISHMENTS: A UXO simulator that allows for the creation of spatial information on the location of individual scrap and UXO pieces across a site was completed. This simulator was developed after it was determined that spatially exhaustive, high-resolution characterization data from a single site do not exist. This simulator allows the user to simulate a variety of patterns of UXO, including airborne and mortar targets, the latter with specified firing area, target and fan shapes and sizes each with different intensities of UXO and scrap. For both kinds of targets, it is possible to specify the radius of fragmentation around a target as a multiplier of the radius of the target zone. The simulator is written to be flexible enough to simulate target locations and geometries that are representative of other types of ordnance.

A Java-based tool was developed for determination of Poisson change points in transect data. These change points can be used as the basis for locating additional sampling transects in the data worth procedure. A program trsamp was written to develop optimal initial sampling plans based on prior information. This program allows the user to determine the rows (across the site) and/or columns (down the site) with the highest mean intensities, highest variance of intensities (as measured across multiple spatial simulations) or the highest probability of exceeding a specified intensity threshold. These rows and/or columns are then chosen as the initial sampling transects. Additionally, trsamp, can supply the user with the locations of the site with the highest mean, variance or probability of exceeding a threshold and then radiate transects out from those locations in the N, S, E, W, NE, or NW directions. This program was used to evaluate the effect of different sampling patterns on the final estimates of UXO.

TRANSITION: In the transition of this technology, it will be necessary to organize and implement a full-scale field demonstration of the characterization procedure developed. Initial planning of this field demonstration and a concise statement of the requirements necessary in a field site will be developed. The techniques and algorithms developed herein will be in the form of research software at the completion of this project. Translation of this research software into a user-friendly package that can be deployed at numerous sights will follow. Commercial vendors with experience in developing software under contract to DoD will be contacted and a technology transfer plan will be implemented.

PROJECT SUMMARY

PROJECT TITLE & ID: Spatial Statistical Models and Optimal Survey Design for Rapid Geophysical Characterization of UXO Sites; UX-1201

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. W.E. Doll; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2002 FUNDS: $332K

DESCRIPTION: Modern geophysical sensor array technologies are being used to fully characterize large potential UXO sites around the world. While the cost per acre for these array-based surveys is often an order of magnitude better than conventional ground surveys, the sheer size of the problem is such that the total end price is still untenable. Statistically valid sampling approaches need to be developed to further reduce the survey footprint.

The proposed approach makes use of the unique advantages of sensor arrays in order to reduce the required sampling area while removing the necessity for complete definition of ordnance distribution. Rather than dividing a homogeneous sector into small grids for detailed investigation (as is currently done in ground-based statistical surveys), a distribution of array swaths is proposed to delineate the boundaries of contamination with higher confidence and lower cost. When a regular pattern of swaths from a sensor array is employed, ordnance density within a sector can be directly mapped (rather than assumed to be uniform) as levels of contamination at a specific measure of uncertainty. This removes the statistical assumption of homogeneity within a sector and can form the basis for remediation decisions and risk assessment. This sub-sampling approach is applicable to any array of sensors collecting a swath of data, whether magnetic or electromagnetic, ground or airborne.

While the technology to conduct these surveys exists, the mathematical foundations and statistical protocols have never been developed. This effort will develop solutions based on the point process theory of spatial statistics. While the locations of UXO are described by spatial point pattern, these locations are not measured directly but are instead observed by an instrument in the proximity of the location (such as a magnetometer) that responds to a physical property of the UXO. Advanced geophysical modeling will be integrated into the study to translate statistical spatial models into measurable parameters.

Ultimately, the purpose of a statistical survey is to reduce the cost of clean up while retaining high confidence of lowering risk posed by UXO. Throughout the process, an assessment of practicability and reliability of the technology has been included. In advance of commitment to a project, confidence measurements are provided through geophysical modeling of targets and statistical modeling of their distributions. Similarly, cost reductions need to be measured in advance of a project. Airborne surveys, for example, have a unique set of operational conditions and cost drivers. In order to adequately set the scope of work for a statistical airborne survey and to calculate the associated cost-benefit-risk factors, a new set of criteria for evaluation needs to be developed alongside a new approach to airborne data processing and interpretation.

BENEFIT: The short-term benefits to DoD of this SERDP project include the development and demonstration of a statistically-valid survey methodology for large scale UXO detection and mapping that is technology independent; significant cost reduction for site analysis related to UXO characterization; and the availability of an analysis package to be used by members of the UXO community. The long-term benefits of this project are a potential reduction in the cost of UXO characterization on millions acres of potentially contaminated land in the U.S.

ACCOMPLISHMENTS: In FY01 project teams from Sandia National Laboratory (SNL) and Pacific Northwest National Laboratory (PNNL) were coordinated. A number of useful data sets and other material on previous UXO-related work conducted by ORNL and the Naval Research Laboratory (NRL) were identified. Splancs, a supplement to the S-plus and R statistical packages with implementations of kernel density estimation and other spatial point pattern methods, was applied to a data set from the Badlands Bombing range. When contamination intensity is estimated from a single large sampled area, the results are good. The theory on how to extend the estimation method to multiple areas (for example, transects or meandering paths) was put into an algorithm. A preliminary evaluation of altitude effects was completed, based on airborne results of the 2001 airborne magnetic survey at Badlands Bombing Range (BBR). The analysis includes a comparison of data acquired at 2, 5, 10, and 20 m with data that were calculated by upward continuation of the 2m data. A preliminary generalized prediction of detectability as a function of mass and the separation (sum of sensor altitude and target depth) was determined. An alternative representations is being considered that might relate sensitivity to target volume (e.g., Altshuler, UXO Forum, 1996), but these distinctions become less important as sensor height increases. Data from other test sites will be folded into this analysis as they become available.

TRANSITION: This project will provide techniques and algorithms in the form of research software. Final validation will require a full scale demonstration at a UXO-contaminated site. The commercialization of individual results, as well as the overall acquisition and statistical methodology, will be examined for transfer to the private sector during appropriate phases of the project, and an appropriate commercialization plan will be provided.

PROJECT SUMMARY

PROJECT TITLE & ID: EM-61-3D Discrimination of UXO Using Empirical, Analytical, and Numerical Models; UX-1215 (*SEED project*)

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Robert Grimm; Blackhawk Geometrics, Inc. – Golden, CO

FY 2001 COMPLETED PROJECT

DESCRIPTION: This research project intended to explore optimization of model-based algorithms for UXO discrimination. Model-based approaches seek to recover physical properties of the target itself (size, shape, orientation, position) and therefore are most useful for target classification. However, there are strong trade-offs between model accuracy and efficiency. Models were tested on existing data acquired by the EM-61-3D, a multicomponent, multichannel pulsed-induction sensor that provides more information than any other readily available electromagnetic instrument.

The team directly compared three approaches to electromagnetic-induction modeling of discrete conductors, quantifying the accuracy and efficiency of each as functions of target size, shape, position, and orientation, A semi-empirical method treats targets as a group of infinitesimal, orthogonal dipoles and constructs responses for arbitrary position and orientation through linear superposition. Classification can be improved by experimentally determining the directional responses of targets of interest. The technique is very fast but is limited to distances relatively far away from the source and receiver, assumes no environmental effects, and can require prior data for each object to be classified. An semi-analytic theory is relatively fast, models the full field at arbitrary distances, and can include ground conductivity, but restricts target shapes to solid triaxial ellipsoids. Numerical models such as the finite-element method offer the most accurate solutions for arbitrary objects and environments but are slow, unsuited to parameter estimation, and require that responses from all potential targets be cataloged. The team tested these three models on existing EM-61-3D test-bed data. If the numerical model is sufficiently accurate, it can be used to generate synthetic data to further define the parameter-space limits to accuracy of the other, approximate models.

BENEFIT: The results of this work will determine whether a sufficient database for the empirical models can be accumulated, whether a database of numerical model results needs to be generated, or whether the compromise semi-analytical theory can adequately address the requirements for both speed and accuracy.

ACCOMPLISHMENTS: Data used to test the models was reviewed and the utility of horizontal channels and time ranges in recovering target orientation was quantified including cross-fitting (e.g., 45-deg inclinations from orthogonal 90-deg measurements). A numeric finite element model was delivered and tested with mean-field theory modifications to the model completed by subcontractor. Parametric (semi-empirical) data fits were also completed. MATLAB analyses and graphical user interface for semi-empirical fits were developed. The response of an 81 mm projectile was modeled with ANSYS EM software. Work was presented at SAGEEP and UXO Forum meetings.

TRANSITION: A full research program following this proof-of-concept study would expand to improved modeling of real UXO and scrap in a greater variety of positions, orientations, and environmental conditions. A follow-on effort would combine test-bed measurements and numerical modeling to define the limits to the empirical and analytical models for a complete range of target sizes and shapes. These techniques will also be useful for optimum sensor design for UXO discrimination. The utility of horizontal-field components and the slightly different time range that distinguish the EM-61-3D from the EM-63 will be assessed in the present work. Future work could study more generally the distribution of time gates required to recover shape parameters for UXO.

The results of all of the research posed here will quantify the accuracy of the empirical and analytic models as functions of target size, shape, position, and orientation. One or both of these models and the appropriate sensors will be transitioned to fielded systems such as MTADS (enhanced for multichannel and/or multicomponent ability), thus enabling the step from detection to discrimination.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Data Analysis; UX-1216 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Dexter Smith; Johns Hopkins University Applied Physics Laboratory– Laurel, MD

FY 2001 COMPLETED PROJECT

DESCRIPTION: Current sensor systems can detect and localize buried metal objects of a wide range of size and depth. These sensors typically measure the active and/or passive magnetic properties of buried metal objects. While current sensor technology has shown the ability to detect these buried objects, the false alarm rate is high because it tends to fail in discriminating the UXOs from metal objects that pose no risk. The development of discrimination algorithms is needed to reduce these false alarms and thus reduce the cost of UXO remediation.

The project objective was to develop algorithms to provide a robust capability to discriminate UXOs from clutter using wide bandwidth electromagnetic induction (EMI) sensor data. Two approaches were used: (1) Develop a technique for target discrimination that combines the spatial and eddy current decay data from buried metal targets. This work will be an extension of the EMI time-domain identification techniques developed for the U. S. Army Countermine Program, and (2) Apply a unique holographic algorithm for imaging the 3-dimensional electromagnetic field beneath the surface using the EMI sensors to determine the location, orientation, and size of the buried metal object.

BENEFIT: The goal of the target discrimination algorithms was to reduce the false alarm rate (FAR) associated with the use of time-domain EMI type sensors. A 50% improvement in the FAR will mean 50% fewer non-UXO targets excavated. This will translate into reduced remediation time and subsequent lower costs.

ACCOMPLISHMENTS: In FY01, the time decay characteristics of a large number of targets from the Blossom Point (BP) experiment were examined. A time decay estimator and match filter algorithm was developed with BP targets used as input. For some targets, there was inconsistent time decay data from spatial measurements over the same target. This may be due uncertain location of the target relative to the EMI antenna, which in turn makes the spatial data uncertain. A metal detector was later used to verify the GPS locations and found that some of the GPS locations were several centimeters away from the peak signal from the metal detector. Garage data taken at BP was used to re-assess the algorithms. Within the second phase of the project, holographic imaging of the targets was analyzed using high density spatial garage data. Automation software was developed to process the data.

TRANSITION: For intellectual property (IP) generated under this effort, the government will be granted a no-cost license consistent with Federal funding statutes and regulations. Additionally, JHU/APL will seek to transfer the technology to the commercial sector by offering standard nonexclusive or exclusive licensing arrangements. Assessing technology insertions opportunities into existing UXO detection programs will follow the systems engineering trade study approach. Here performance, schedule, cost, and risk of the new technology or combinations of technologies will be examined and presented to government program managers. Concepts of operation for each program platform will be examined for compatibility with any technology improvements recommended for inclusion.

PROJECT SUMMARY

PROJECT TITLE & ID: A Unified Approach to the Processing and Fusion of Time and Frequency Domain EMI Data for UXO Discrimination; UX-1217 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Eric Miller; Northeastern University – Boston, MA

FY 2001 COMPLETED PROJECT

DESCRIPTION: The objective of this project was to better understand the utility of time domain and frequency domain EMI data for UXO discrimination and to develop algorithms that optimally make use of both classes of information when the position and orientation of the object are uncertain. The critical issues addressed during this effort involve the development and validation of statistical processing methods based on simple, yet accurate, physical models which will allow UXO to be successfully discriminated from clutter when the position and the orientation of the object are not known with certainty and given data from time and frequency domain sensors collected at arbitrary points in space. Additionally, methods for fusing EMI sensor data were examined to determine both how this might be done and whether there is significant performance benefit from such fusion. Further development would be warranted should these methods prove capable of high rates of successful classification with low rates of misclassification as demonstrated using real sensor data.

BENEFIT: The computational complexity of both the models and the processing schemes is relatively low. It is anticipated that a Matlab implementation running on a Pentium machine should produce discrimination results from data in the range of one to five minutes. The speedup using a C or Fortran implementation implies that our methods will be well suited for use in the field in conjunction with state-of-the-art sensors. The primary cost of further development is the coding of the methods in a lower level language than Matlab and the incorporation of these codes into existing systems. The primary benefit will be improvements in the discrimination of UXO from clutter.

ACCOMPLISHMENTS: Methods for classifying objects based on spatially sampled electromagnetic induction data taken in the time or frequency domain have been developed and analyzed. To deal with nuisance parameters associated with the position of the object relative to the sensor as well as the object orientation, a computationally tractable physical model explicit in these unknowns has been developed. The model is also parameterized by a collection of decay constants (or equivalently Laplace-plane poles) whose values in theory are independent of object position and orientation. These poles are used as features for classification.

The overall algorithm consisted of two stages. First the values of the unknown parameters were estimated and then classification was completed. Three classification schemes were examined. The first is based on data residuals. The second uses estimated pole values. The third is a blending of the first two. Preliminary results on synthetic data indicate the robustness of the pole estimates as features for classification and point toward the need for further analytical as well as experimental evaluation of the proposed methods. Real sensor data was evaluated to test and validate the algorithms and reassess the classification methods.

TRANSITION: Transition opportunities exist with DoD/DOE associates such as Geophex, GeoCenters, EG&G, NRL, and Coleman, all of whom make use of EMI sensors and all of whom would potentially benefit from the work done under this project. The principal investigator has worked with the first three members of this list and has current collaboration underway with EG&G on a GPR-related processing project.

PROJECT SUMMARY

PROJECT TITLE & ID: Detection and Classification of Buried Metallic Objects; UX-1225

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. H. Frank Morrison; DOE, Lawrence Berkeley Laboratory – Berkeley, CA

FY 2002 FUNDS: $442K

DESCRIPTION: The project will perform basic research to develop a systematic approach for design and fabrication of an optimum active electromagnetic (EM) system based on the methodology employed in the minerals exploration industry in the search for metallic ore bodies. The intent of the optimum system, bounded by practical and theoretical limitations, is to detect, discriminate and classify to an agreed upon criterion or specification. The design of the optimum system will be achieved through the integration of: (1) A comprehensive set of simulators for determining the response of arbitrary conducting, permeable bodies; (2) A simple algorithm that determines the principal moments of a target and computes the band-limited frequency spectrum or the transient decay of the response in the principal axis directions; (3) A technical assessment of the current systems and the proposed optimal system, with particular emphasis on the ambient and geological noise levels; and (4) The design parameters for the construction of an optimal prototype.

BENEFIT: The project intends to develop an active EM system that can extract the measurements for the best possible estimates of the location, size, shape and metal content of a buried metallic object in the presence of an interfering response from the ground and/or non-UXO metallic objects. The objective is to design an optimum system which provides the best detection of UXO with the lowest field survey cost.

ACCOMPLISHMENTS: In FY01, the project adapted and improved an existing Mean Field Theory (MFT) 3-D modeling code. The code, suited for computing EMI response of UXO, was modified to extend to response times an order of magnitude earlier than were previously attainable. A computer model was developed to simulate the EMI response of a spherical shell and the possibility of discriminating between hollow and solid objects was examined. The Principal Dipole Moment (PDM) concept for active EM systems was tested and determined to be adequate. In addition, an investigation has been commenced to determine the effect of receiver bandwidth on system response. Initial results indicate this may be an important factor in developing the parameters of an optimal system.

TRANSITION: The project intends to transition the tools to the Environmental Security Technology Certification Program (ESTCP).

PROJECT SUMMARY

PROJECT TITLE & ID: Signal Processing and Modeling for UXO Detection and Discrimination in Highly Contaminated Sites; UX-1281

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Leslie Collins; Duke University – Durham, NC

FY 2002 FUNDS: $335K

DESCRIPTION: Until recently, detection algorithms could not distinguish between buried UXO and clutter, leading to many false alarms. Over the last several years modern geophysical techniques have been developed, merging more-sophisticated sensors, underlying physical models and statistical signal processing algorithms, with such approaches yielding reduced false alarms. In particular, for sites where anomalies are well separated, it has been shown that the combination of phenomenological models and advanced signal processing can markedly decrease the time required to remediate a site by classifying UXO and non-UXO items correctly. For highly contaminated regions, however, the signatures of multiple anomalies often overlap, vitiating the utility of many of the newer techniques. To address this problem a synergistic use of advanced phenomenological-modeling and signal-processing algorithms will be employed.

The proposed research program has two principal objectives: (1) The development of new physics-based signal-processing approaches applicable to scenarios in which responses from multiple UXO and clutter items co-exist in a sensor signal, with the goal of discrimination; and (2) The use of information-theoretic measures to define the types of scenarios for which UXO and clutter density is too high to reliably perform classification, necessitating a direct mechanical excavation of an entire region. The first objective will be met by the parallel development of phenomenological models and statistical signal processing algorithms. The latter topic will address circumscription of those regions, presumably in the vicinity of a former bull's-eye, for which discrimination of individual UXO and clutter is intractable due to the high density of target/clutter overlap and the limited information in available sensor data.

BENEFIT: The phenomenological models will allow quantification of the performance of UXO sensors as a function of object density. The models will also provide a realistic method of generating training data upon which algorithms can be tested. This precludes the need for extensive field data collections, although field collections will be required for final algorithm testing. Such training data sets will hasten the transition from algorithm development to deployment, and also will facilitate assessment of algorithm robustness. The algorithms that will be developed will provide the ability to separate the signatures associated with different subsurface objects from a composite signature measured by a sensor. Accurate separation of such signatures will permit remediation of sites that cannot currently be considered using conventional techniques. The output of such algorithms can be transferred to discrimination algorithms that have already proven to improve discrimination of UXO from clutter. The signal processing research will result in performance bounds that allow assessment of sensor performance as a function of site parameters. These bounds will also be useful for circumscription of areas for which predicted discrimination performance falls below acceptable levels.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The project will pursue teaming relationships and will transition algorithms and model codes to the sensor developers and users in the field as they mature. Collaborative relations so organized will provide focus for developments such that they are of use to practical systems. Moreover, these organizations, which are responsible for hardware design and measurement campaigns, will gain insight from phenomenological models to assure that the systems are designed and deployed in the most salutary fashion.

PROJECT SUMMARY

PROJECT TITLE & ID: UXO Discrimination in Cases with Overlapping Signatures; UX-1282

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Kevin O'Neill; U.S. Army Corps of Engineers Engineer Research and Development Center, Cold Regions Research and Engineering Laboratory – Hanover, NH

FY 2002 FUNDS: $400K

DESCRIPTION: The intent of this project is to perform basic research on the use of electromagnetic induction (EMI) sensors and ground penetrating radar (GPR), together, to develop the means for substantially improving buried UXO discrimination at highly contaminated sites where different signatures overlap. The assumption is that detection has been accomplished and detailed surveying is to be performed around an indicated location. Instrumentation, measurement techniques, modeling and signal analysis will be further developed to enable ultra-wideband (UWB) sensing in multi-position survey schemes around suspected target clusters.

Specific problems addressed are: (1) The case of two or three UXO-sized objects, (2) The "fragment cloud" consisting of many small clutter items that could have the same amount of metal as a UXO, and (3) The screening problem when a single UXO-sized object is amidst or beneath a distribution of smaller fragments. Both EMI and GPR will be used to address all three cases.

BENEFIT: The results of this project will: (1) Support development of subsurface sensing and processing systems that will take advantage of broadband data in both electromagnetic induction sensing and ground penetrating radar; and (2) Enhance our ability to discriminate UXO from clutter. This will result in cheaper, more efficient, and especially more reliable surveying for UXO site cleanup.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: This project will perform basic research applying electromagnetic physics to provide an improved basis for discrimination of UXO from clutter in highly contaminated sites, that is, where signatures of different objects overlap. The result will be further development of instrumentation measurement techniques, modeling and signal analysis to enable ultra-wideband sensing in multi-position survey schemes around suspected target clusters.

PROJECT SUMMARY

PROJECT TITLE & ID: Physics-Based Modeling and Signal Processing for SAR Detection of Former Bombing Ranges and Burial Pits; UX-1283

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Lawrence Carin; Duke University – Durham, NC

FY 2002 FUNDS: $175K

DESCRIPTION: There is significant interest in developing sensors that can effectively interrogate large areas for UXO detection in the presence of realistic rough and/or vegetated terrain. For this problem detection of each UXO at a significant standoff would be ideal. However, more realistically, a large standoff sensor is required to interrogate thousands of acres quickly, with the goal of circumscribing those areas that are most likely to be contaminated by UXO. In this context, rather than requiring detection of each UXO, the goal is detection of a former bombing range (i.e., detection of a high enough percentage of individual UXO to delineate a former bombing range). Similar issues hold with regard to detecting a burial pit. One of the few sensors that affords wide area surveillance, at a significant standoff, is synthetic aperture radar (SAR). While SAR is not in general appropriate for detecting each individual UXO, particularly those that are small and/or deeply buried, it can detect shallow buried and surface UXO. The principal challenge is detection of a high percentage of such UXO, at a low false alarm rate, such that one can circumscribe a region for subsequent ground-based detection.

The approach studies the utility of SAR for wide area detection of UXO in the presence of naturally occurring clutter. It is understood that, even for this limited problem class, SAR will not be appropriate for all environments. Therefore, rigorous electromagnetic models will be employed with state of the art signal processing tools to investigate UXO detection in the presence of various soil types, surface roughness, vegetation and subsurface inhomogeneties.

BENEFIT: The electromagnetic models, having been developed and refined for many years, represent a significant asset that will be brought to bear on any future SAR-based UXO program, significantly furthering the transition from optimal sensor design to subsequent sensor deployment. Utilization of the software developed under this program is very inexpensive, given computer resources. Moreover, use of the insight from the software, in the design of an optimal SAR system and associated processing algorithms, can be very cost effective in assuring that the system is properly designed and deployed. Insights gained computationally are far less expensive and time consuming than those learned empirically.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The algorithms will be tested using available SAR imagery, from previous ARL data collections, anticipated collections from DARPA, as well as future measurements from other projects. Based on this modeling, and the associated signal processing discussed below, utility of SAR for wide-area detection of UXO in the presence of naturally occurring clutter will be addressed. It is understood that, even for this limited problem class, SAR will not be appropriate for all environments.

PROJECT SUMMARY

PROJECT TITLE & ID: Application of Wavelets for Detection and Discrimination of UXO; UX-1284 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Brian Damiano; Oak Ridge National Laboratory – Oak Ridge, TN

FY 2002 FUNDS: $96K

DESCRIPTION: Airborne methods for detecting unexploded ordnance (UXO) can realize large cost and time savings compared to ground-based detection methods. However, existing data processing tools may not enable this data collection to be as sensitive to small objects as it is capable of being, or as sensitive as methods that use surface deployed instrumentation. The aim is to use wavelet analysis of magnetic signatures acquired from airborne platforms to remove noise and discriminate between clutter and targets.

Two approaches, each using wavelet analysis, will be investigated. In the first approach, profile data collected at sites with seeded anomalies will be analyzed by using current signal processing methods and the discrete wavelet transform (DWT). It is anticipated that the DWT-based method will be easier and faster to apply, result in noise removal, and probably be superior to that obtained by existing methods. A variety of wavelet types will be used to determine which wavelet is best suited to the analysis of the profile data.

The second approach will apply the continuous wavelet transform (CWT) to profile data. This application results in a three dimensional representation of the signal; the "x" direction represents time and the "y" direction represents inverse frequency, and the "z" direction represents signal strength. By using a color map to represent the signal strength, the result of the CWT is an image in which signal features appear as "blob-like". The aim is to use image processing techniques to extract and classify image features, with the intent being to discriminate between clutter and targets.

BENEFIT: The application of wavelet analysis to profile magnetic data is a novel alternative to current filtering techniques. The increase in the signal-to-noise ratio is expected to result in a more accurate and detailed description of stronger targets that are currently detectable. This increase in available detail may make it easier to distinguish between multiple overlapping targets as well as discrimination between targets and clutter.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: A significant number of tangible products and results will be provided that will have direct application to DoD and other ordnance-laden land. The commercialization of individual results, as well as the overall acquisition strategy developed through this project, will be examined for transition to the private sector during this project.

PROJECT SUMMARY

PROJECT TITLE & ID: Evaluating the Effects of Magnetic Susceptibility in UXO Discrimination Problems; UX-1285 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Yaoguo Li; Colorado School of Mines – Golden, CO

FY 2002 FUNDS: $100K

DESCRIPTION: Magnetic and electromagnetic surveys have a well-documented ability to locate UXO but are prone to false alarms, which increases the cost of cleanup. The key to reducing false alarms is the development of algorithms that can discriminate between an intact UXO and other items such as scrap metal or geological features.

The purpose of this study is to determine how magnetic soils affect the recovered parameters from magnetic and electromagnetic (EM) inversions and, if significant, to explore possible techniques to mitigate their effects. Forward modeling of magnetic and Em data for UXO items embedded in media with arbitrary distributions of susceptibility will be used to understand the effects of susceptibility on the two data types. Results will be used to assess conditions under which such noise affects the results of inversion calculations. Methods for removing susceptibility noise from magnetic and Em data will be investigated.

BENEFIT: The focus of the project is on characterizing situations where the susceptibility of the soil significantly degrades the ability to discriminate when using the recovered parameters from magnetic and time-domain EM inversions. The study will: (1) quantitatively evaluate the effects of background susceptibility and determine under what conditions inversion algorithms can work; (2) determine how the data can be modified so that the current inversion algorithms will work in the presence of background susceptibility; and (3) possibly provide an explicit action plan for future inversion research that must contend with recovering information about the background susceptibility and the UXO at the same time.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The project intends, if the technology is developed, to provide an effective means to minimize false alarm rates in UXO clean-ups. Potential users of the technology may include the U.S. Army Corps of Engineers at such problematic areas as Fort Ord or Kaho'olawe.

PROJECT SUMMARY

PROJECT TITLE & ID: Algorithms for Discriminating UXO from Non-UXO Based on Mathematical Morphology and Fuzzy Sets; UX-1286 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Paul Gader; University of Florida – Gainesville, FL

FY 2002 FUNDS: $99K

DESCRIPTION: The goal of the proposed research is to investigate the applicability of the methods of mathematical morphology and fuzzy sets to the problem of discriminating UXO from non-UXO signatures using data from state-of-the-art sensors. These methods have been applied with success to similar discrimination problems in the past and preliminary studies suggest that they will be useful for UXO discrimination.

The methods of mathematical morphology and fuzzy sets will be applied to signature data acquired from state-of-the-art sensors, such as EMI, Magnetometer, or GPR sensors. Algorithms will be developed that process sensor data and make determinations as to the likelihood that the data was measured on a UXO item or not. The signature data will be measured by other contractors during a significant data collection in the field.

BENEFIT: High false alarm rates result in increase clean-up costs. With improved discrimination techniques, these costs will be mitigated. It is believed that proposed methods will be useful for UXO. Their success in other problem domains and the lack of investigation of these methods in the UXO domain will be investigated.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: Upon demonstration of enhanced capability utilizing the algorithms, the work will be transitioned to contractors who collect the data to perform further processing.

PROJECT SUMMARY

PROJECT TITLE & ID: Improving UXO/Clutter Discrimination Performance through Adaptive Processing; UX-1287 *(SEED project)*

PRINCIPAL INVESTIGATOR & ORGANIZATION: Dr. Thomas Bell; AETC, Inc. – Arlington, VA

FY 2002 FUNDS: $100K

DESCRIPTION: Buried unexploded ordnance (UXO) is one of the Department of Defense's most pressing environmental problems. Current technology has shown the ability to detect individual sub-surface UXO but not to reliably discriminate UXO from other items in the ground that pose no risk. To address this problem, this project intends to introduce an adaptive processing approach that incorporates sensor position adjustments into the fitting algorithms used to invert electromagnetic induction (EMI) data. It is anticipated that this will improve discrimination performance in the face of inaccurate sensor location data.

Past discrimination performance from the Naval Research Lab (NRL) and Geophex will be evaluated. In developing the position adjustment algorithms, the focus initially will be on the EM61 system since there is less information to deal with. Various techniques for correcting errors in the sensor position measurements will be assessed. The idea is to determine which works best, since each will have its own qualities relating to robustness and convergence rates. At a minimum, three approaches will be considered: (1) Adaptive and low-pass filtering, (2) Application of hidden Markov models to track and predict the system motion, and (3) Application of simultaneous hidden Markov models to the system motion and tilt. These techniques will first be applied to simulated data, in which the sources of error and ground truth are known so that the performance of the various algorithms can be compared. The algorithms will then be applied to measured data that has been collected with a cart-based system in order to evaluate the robustness of the performance.

BENEFIT: The project intends to incorporate sensor position adjustments into the fitting algorithms, and improve target classification and discrimination performance beyond the limits imposed by the inherent errors in sensor location measurements. Performance of processing algorithms for discrimination are limited by errors introduced by positioning problems. Once these effects have been alleviated, more complex signal models can be used.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The track compensation procedures developed under this project will be directly transitioned into the Multi-Sensor Towed Array Detection System (MTADS) Data Analysis System, as well as other software packages. This will allow more sophisticated processing algorithms that include multiple target and non-dipole models.

PROJECT SUMMARY

PROJECT TITLE & ID: Standardized UXO Technology Demonstration Sites Program; UX-1300

PRINCIPAL INVESTIGATOR & ORGANIZATION: Mr. George Robitaille; U.S. Army Environmental Center - Aberdeen Proving Grounds, MD

FY 2002 FUNDS: $504K

DESCRIPTION: Advancements in UXO detection and discrimination technologies are necessary to support the operation, restoration, and transfer of the DoD's ranges. UXO characterization technologies can be affected by variations in site terrain, geology, vegetative cover and weather conditions encountered. The establishment of standardized UXO technology demonstration sites will allow users and developers to define the range of applicability of specific UXO technologies, gather data on sensor and system performance, compare results, and document realistic cost and performance information.

In order to satisfy both the research and development community and the technology demonstration community, the standardized sites will be made up of three areas, a calibration lane, a blind grid, and an open field. The calibration lane will allow demonstrators to test their equipment, build a site library, document signal strength, and deal with site-specific variables. The blind grid allows the demonstrator to showcase the sensors on their system without platform, coordinate system, or operational concerns. The open field will document the performance of the entire system in actual range operations.

BENEFIT: This program will ensure that critical UXO technology performance parameters such as detection capability, false alarm rates, discrimination, reacquisition, and system efficiency are determined through standardized test methodologies, procedures, and facilities. The Standardized UXO Technology Demonstration Site Program involves collaboration of several organizations and will build on the experience and expertise of each of the participants to establish realistic and cost effective standardized demonstration sites.

ACCOMPLISHMENTS: This is a FY 2002 New Start.

TRANSITION: The Standardized UXO Technology Demonstration Site Program will provide the UXO technology developer with "turn key" standardized sites for UXO sensor technology testing and demonstration. Other products resulting from the program include a screening matrix of system performance, a series of standardized site protocols, a standardized target repository, a technology-screening matrix, and a variety of technology transfer and marketing materials. The first two installations selected to implement a standardized site are Aberdeen Proving Ground (APG) and Massachusetts Military Reservation (MMR). Standardized site development will begin at APG with the knowledge and the experiences gained being transferred to the second site at MMR.

APPENDIX F
Statements of Need

This appendix contains brief summaries of all SERDP Statements of Need (SON) released in the past year. The objectives of SERDP are to support environmental research and development projects to meet high priority, DoD mission-related environmental needs. The major annual, or "**Core**," solicitation occurs each year and provides funding in various amounts for multi-year projects. The **SE**RDP **E**xploratory **D**evelopment, or **SEED**, solicitation also occurs annually and is a means for researchers to test proof-of-principles concepts during an effort of one year or less. The SEED program is designed to provide support for high-risk, high-payoff projects in which funding is limited to a maximum of $100,000 for one year.

In addition to the Core and SEED annual solicitations, SERDP released three other solicitations. The Live Fire solicitation was issued in response to Congressional direction to examine the environmental impacts of live fire training on military ranges. The Perchlorate solicitation was released to examine the impact of environmental exposures to perchlorate in a variety of animals. Late in 2001, a Supplemental solicitation for FY 2002 projects was released as a result of an unanticipated increase in the FY 2002 President's Budget for SERDP.

CLEANUP

COMPLIANCE

CONSERVATION

POLLUTION PREVENTION

FY 2003 SEED Solicitation:

UNEXPLODED ORDNANCE (UXO)

FY 2002 Supplemental Solicitation:

FY 2003 SEED Solicitation:

LIVE FIRE SOLICITATION STATEMENT OF NEED FOR FY 2001
CLEANUP – CUSON-01-06

SCREENING LEVEL ASSESSMENT OF ENERGETIC CONTAMINATION

OBJECTIVE: The objective of this Statement of Need (SON) is to seek fundamental or applied studies to develop innovative, rapid screening technologies to detect and delineate land areas with soils containing contaminants associated with live fire training activities including energetic compounds (RDX, HMX, TNT, DNT), propellants, and their byproducts. Identification and quantification of specific compounds is desired but is of secondary importance. This SON does not solicit technologies for the detection of unexploded ordnance, but rather for detection of energetic chemical constituents in soil.

The focus of this SON is to develop screening tools that will be used in the rapid, initial screening assessment of large DoD testing and training ranges in order to locate and delineate potential zones of soil contamination that require more detailed follow-on characterization. Successful screening technologies will enhance the ability to perform cost-effective and rapid assessments of large land areas within testing and training ranges to identify potential source areas of energetic contamination.

BACKGROUND: There exists a growing concern about the potential of military training activities leading to groundwater contamination on DOD ranges. One example of this situation exists at the Massachusetts Military Reservation (MMR). Military and law enforcement training has been conducted for over forty years in the Training Range and Impact Area, which encompass almost 14,000 acres at MMR. The Training Range and Impact Area lie directly over the Cape Cod Aquifer, which has been designated as a sole drinking water source for Cape Cod. The detection of energetic compounds in the groundwater beneath the Training Range and Impact Area demonstrates the potential for military training activities to cause groundwater contamination. There is a need to develop technologies to rapidly screen the millions of acres of DoD lands suspected of having soil contaminated with energetic compounds. Technologies that permit stand-off, large area screening would be advantageous.

LIVE FIRE SOLICITATION STATEMENT OF NEED FOR FY 2001
CLEANUP – CUSON-01-07

CONTAINMENT OF SOURCE ZONE ENERGETIC CONTAMINATION

OBJECTIVE: The objective of this Statement of Need (SON) is to seek fundamental or applied studies to develop innovative technologies to prevent migration of surface and near surface (< 1 foot below ground surface) soil contamination by energetic materials (RDX, HMX, TNT, and DNT) that may act as a source zone for groundwater contamination on DOD testing and training ranges. Technologies should be applicable to large, potentially vegetated areas and may employ physical or chemical containment/immobilization/sequestration approaches. Migration pathways of concern include surface run-off and subsurface migration/leaching to groundwater. Landfill capping technologies will not be considered under this SON.

The research should focus on developing a better understanding of the approaches needed to contain energetic contamination source zones on large vegetated areas. The energetic contaminant of primary concern is RDX due to its low federal health advisory level and its ability to migrate quickly through the soil matrix, but HMX, TNT and DNT are also of interest. Results from this research will aid in developing a better understanding of the physical and chemical behavior of energetic materials in source areas, which may be introduced as particles and fragments of varying size. Results from this research will aid in developing energetic source zone containment and/or treatment strategies. This improved understanding of source containment for energetic contamination should result in more cost-effective remediation strategies at DoD sites.

BACKGROUND: There exists a growing concern about the potential for military training activities leading to groundwater contamination on DOD ranges. One example of this situation exists at the Massachusetts Military Reservation (MMR). Military and law enforcement training has been conducted for over forty years in the Training Range and Impact Area, which encompass almost 14,000 acres at MMR. The Training Range and Impact Area lie directly over the Cape Cod Aquifer, which has been designated as a sole drinking water source for Cape Cod. The detection of energetic compounds in the groundwater beneath the Training Range and Impact Area demonstrates the potential for military training activities to cause groundwater contamination. There is a need to develop technologies to contain energetic contamination within the soil of the source zone so that it will not lead to groundwater contamination.

LIVE FIRE SOLICITATION STATEMENT OF NEED FOR FY 2001
CLEANUP – CUSON-01-08

CONTAINMENT AND TREATMENT OF ENERGETIC COMPOUNDS IN GROUNDWATER

OBJECTIVE: The objective of this Statement of Need (SON) is to seek fundamental or applied studies to develop innovative in-situ technologies to contain and/or treat energetic compounds (RDX, HMX, TNT, and DNT) in groundwater. Of primary interest are large groundwater plumes associated with sources on DoD live fire ranges. Technologies should be effective for initial contaminant concentrations ranging from tens to hundreds of parts per billion. Traditional plume containment approaches, e.g. hydraulic containment, will not be considered under this SON.

The primary contaminant of concern is RDX due to its low federal health advisory level and its ability to migrate quickly through the soil matrix, but HMX, TNT, and DNT are also of interest. The results from this research should lead to an understanding of the effectiveness and limitations of innovative containment/treatment approaches for large energetic contaminated groundwater plumes emanating from ill-defined source areas on military testing and training ranges. Results from this research will lead to the development of treatment strategies for groundwater contaminated with energetic compounds. An improved understanding of innovative technologies for groundwater containment/treatment should result in more cost-effective remediation strategies being employed at DoD sites.

BACKGROUND: There exists a growing concern about the potential for military training activities leading to groundwater contamination on DOD ranges. One example of this situation exists at the Massachusetts Military Reservation (MMR). Military and law enforcement training has been conducted for over forty years in the Training Range and Impact Area, which encompass almost 14,000 acres at MMR. The Training Range and Impact Area lie directly over the Cape Cod Aquifer, which has been designated as a sole drinking water source for Cape Cod. The detection of energetic compounds in the groundwater beneath the Training Range and Impact Area demonstrates the potential for military training activities to cause groundwater contamination. There is a need to develop technologies for the efficient and cost-effective cleanup of these groundwater plumes.

PERCHLORATE SOLICITATION STATEMENT OF NEED FOR FY 2001
CLEANUP – CUSON-01-09

IMPACTS OF ENVIRONMENTAL EXPOSURES TO AMMONIUM PERCHLORATE ON FISH, AMPHIBIANS, AND SMALL RODENTS

OBJECTIVE: The purpose of this statement of need (SON) is to examine the impact of environmental exposures of ammonium perchlorate on avian species, small rodents, amphibians and fish.

The Interagency Perchlorate Steering Committee (IPSC) has identified avian exposure studies as a data gap. Research is needed in the following specific areas: (i) development of assessment endpoints for specimens in areas of contamination including perchlorate and hormone concentrations in adults; reproductive success; survival, growth, and development of chicks; and transfer of perchlorate to eggs, (ii) the evaluation of food items as sources of perchlorate contamination to avian species, (iii) laboratory-dosing studies to establish safe exposure levels for avian species, and (iv) development of PBPK models for avian species.

Food item transfer of perchlorate into rodents will be studied to determine the viability and efficiency of exposure routes other than the ingestion of water. There are preliminary indications that there are a number of important potential exposure routes in addition to the ingestion of water, such as ingestion of food items and incidental ingestion of soil. This research should help to determine the level of perchlorate exposure to rodents via ingestion of contaminated media other than drinking water.

Research related to amphibians is needed in the following specific areas: (a) Combined effects of solar ultraviolet (UV) light and perchlorate on amphibian development, melanocytes & DNA damage; (b) Influence of iodide on perchlorate toxicity in amphibians; (c) Effects of perchlorate on amphibians; and (d) Evaluation of perchlorate toxicity in native species of amphibians.

Research is needed to determine the uptake, elimination, and accumulation of perchlorate in different species of fish at different trophic levels for ecological risk assessments and construction of food web models of fate of ammonium perchlorate in the environment. Determining the relative contribution of perchlorate in food versus water in uptake and effects of perchlorate in fish is also of interest. In addition, research will focus on reproductive assessment in native species of fish exposed to perchlorate.

Research is needed to adapt and incorporate a plant model into an aquatic food chain model. A number of studies have indicated that perchlorate readily accumulates into plant tissues. However, little is known about the contribution of contaminated plants to exposure in aquatic consumers. Therefore, research is needed to develop models that are predictive of food chain exposure based on the contribution of plant materials. Since perchlorate is extremely water-soluble, aquatic food chains are potentially susceptible to perchlorate exposure and effects.

BACKGROUND: Perchlorate, a persistent water soluble chemical, is used as an oxidizer component in solid propellant (fuel) for rockets, missiles, and fireworks. Perchlorate has also been found in some fertilizers. Recent (April 1997) advances in low level analytical detection capability for perchlorate have led to the discovery of perchlorate at various manufacturing, military, and other sites. Since April 1997, perchlorate has been found in water supplies in Arizona, California and Nevada and reported in surface or groundwater in 11 other states. The perchlorate anion ($ClO4-$) is exceedingly mobile in aqueous systems and can persist for many decades under typical groundwater and surface water conditions, due to kinetic barriers to its reactivity with other available constituents. This mobility and persistence may pose a threat to ecological receptors and whole ecosystems, either by direct harm to organisms, or it may indirectly affect their ability to survive and reproduce.

SUPPLEMENTAL STATEMENT OF NEED FOR FY 2002
CLEANUP – CUSON-02-03

CONTAINMENT/TREATMENT OF ENERGETIC MATERIAL RELEASES ON TESTING AND TRAINING RANGES

OBJECTIVE: The objective of this Statement of Need (SON) is to seek fundamental or applied studies to develop innovative technologies capable of sustained prevention of migration of surface and near surface (<1 ft below ground surface) soil contamination by energetic materials (RDX, HMX, TNT, and DNT) that may act as a source of groundwater contamination on DoD testing and training ranges. Technologies should be applicable to large, potentially vegetated areas and should be directed to long-term control of energetic materials either through repeated applications of relatively inexpensive and rapidly deployable technologies or through self-sustaining treatment technologies such as phytoremediation. Periodic inputs of energetic materials will occur over the long-term and treatment technologies must be adaptable to an unpredictable influx of contaminants. Technologies may employ physical, chemical, or biological containment, immobilization, sequestration, or transformation approaches. Migration pathways of concern include surface run-off and subsurface migration/leaching to groundwater. Potential technologies of interest include, but are not limited to, immobilization, sequestration, and phytoremediation via native or genetically engineered plants. Landfill capping technologies will not be considered under this SON.

The research should focus on developing a better understanding of the approaches needed to contain energetic contamination source zones on large vegetated areas over the long term. The energetic contaminant of primary concern is RDX due to its low federal health advisory level and its ability to migrate quickly through the soil matrix, but HMX, TNT, DNT and their breakdown products are also of interest. Results from this research will aid in developing a better understanding of the physical and chemical behavior of energetic materials in source areas, which may be introduced as particles and fragments of varying size. Research and development activities at laboratory-, bench-, and field-scale will be considered, but work does not necessarily have to culminate in a field-scale effort. Results from this research will aid in developing long-term energetic source zone management strategies to minimize or eliminate the potential for energetic contaminants migrating/leaching to groundwater.

BACKGROUND: There exists a growing concern about the potential for military training activities leading to groundwater contamination on DOD ranges. One example of this situation exists at the Massachusetts Military Reservation (MMR). Military and law enforcement training has been conducted for over forty years in the Training Range and Impact Area, which encompass almost 14,000 acres at MMR. The Training Range and Impact Area lie directly over the Cape Cod Aquifer, which has been designated as a sole drinking water source for Cape Cod. The detection of energetic compounds in the groundwater beneath the Training Range and Impact Area demonstrates the potential for military training activities to cause groundwater contamination. There is a need to develop technologies to contain energetic contamination within the soil of the source zone so that it will not lead to groundwater contamination.

CORE STATEMENT OF NEED FOR FY 2003
CLEANUP – CUSON-03-01

DNAPL SOURCE ZONE DELINEATION AND CHARACTERIZATION

OBJECTIVE: The objective of this Statement of Need (SON) is to develop technologies and approaches to delineate and characterize chlorinated solvent DNAPL source zones. Specific objectives include: (1) develop better tools and procedures to delineate and characterize dense nonaqueous phase liquid (DNAPL) source zones, and (2) develop protocols and guidance for cost-effectively characterizing source zones using existing and/or new technologies to aid in selection and design of remediation options. Technologies and approaches should be applicable to a variety of hydrogeologic settings as well as to a variety of source zone configurations. Tools and procedures that aid in our assessment of the impact of source zones on surrounding groundwater as well as the design of treatment options are desired.

Research on improved site characterization techniques should lead to methods that provide the types of information needed for remediation system selection and design. Site characterization often constitutes a large portion of the overall budget and time of a remedial effort. A practical assessment of critical data needs to complete system design is essential when developing site characterization technologies. The contaminants of concern include tetrachloroethene (PCE), trichloroethene (TCE), and their breakdown products. Results from this research will aid in developing a better understanding of the nature and extent of DNAPL source zones and in creating a realistic approach to source zone characterization recognizing the inherent limitations.

BACKGROUND: Although DoD facilities have numerous types of contaminants, chlorinated solvents are by far the most prevalent, particularly TCE and PCE, but related compounds such as trichloroethane (TCA), vinyl chloride (VC), dichloroethenes (DCE), and carbon tetrachloride (CT) also represent significant concerns. Because of their recalcitrant nature, these chlorinated aliphatic hydrocarbons (CAHs) also remain among the most difficult to remediate, despite several years of research and development. The delineation of DNAPL sources is a long-term problem that makes any approach to assessing and remediating CAH-impacted groundwater extremely difficult. But even if one can fully define the boundaries of a source zone, remediation will be difficult unless one can also characterize its attributes in a meaningful way.

At present, DNAPL source zones are identified by indirect means, primarily by inference from groundwater and soil concentration data. There are no accepted tools or test protocols available for the direct measurement of DNAPL composition and mass in the subsurface. There has been progress in developing and testing new approaches to DNAPL detection and quantification of DNAPL extent in the subsurface, such as partitioning tracer tests, use of radon abundance data, and geophysical surveys. While these methods may be helpful in locating DNAPL source zones, they are still indirect techniques that will provide limited or no information on DNAPL composition and mass. Realistic composition and mass measurements require direct measurement analytical techniques or assessment protocols that involve several kinds of measurements.

The physical and chemical attributes of source zones are currently difficult to evaluate, yet these features can have important influences on the feasibility, selection, design, and performance of remediation technologies. These attributes include both the macro-scale and local distributions of DNAPL in the subsurface, as well as the chemical composition of the DNAPL. The macro-scale distribution of DNAPL defines the overall geometry of the source zone and is an important determinant of the total mass/volume of DNAPL that is present. The local distribution of DNAPL is equally important, because DNAPL present in sub regions of fine-grained material is less accessible to remediation agents than that present in sub regions of coarse material. The chemical composition of the DNAPL, influenced by historic releases and subsequent weathering, affects interfacial tension, viscosity, density, wettability, and other interactions at the DNAPL-mineral interfaces, as well as the potential for enhanced and natural biodegradation.

CORE STATEMENT OF NEED FOR FY 2003
CLEANUP – CUSON-03-02

DIAGNOSTIC PROCEDURES TO EVALUATE REMEDIATION PERFORMANCE AT CHLORINATED SOLVENT-CONTAMINATED SITES

OBJECTIVE: The objective of this Statement of Need (SON) is to seek fundamental or applied studies to (1) develop diagnostic procedures to evaluate the performance of chlorinated solvent source zone and/or groundwater plume in-situ remedial technologies and (2) develop better technical guidance on using diagnostic procedures to improve our ability to determine technology-limited remedial endpoints at chlorinated solvent-contaminated sites. The term diagnostic procedure may be defined as procedures or techniques that allow for relatively rapid assessment of a defined set of physical, chemical, or biological parameters that may be used as analogues for "diagnosing" and or predicting system technical performance. Diagnostic procedures should be able to provide data that would complement or ultimately replace relatively expensive, traditional performance measurement techniques such as groundwater and soil sampling.

Diagnostic procedures for source zone treatment technologies are of most interest, but research that focuses on technologies implemented in the groundwater plume will also be considered. Diagnostic procedures should be applicable to a variety of hydrogeologic settings as well as to evaluation of technologies at various stages of the remedial process, including pilot-scale testing, active operation, and post-monitoring. Research should focus on developing diagnostic procedures that provide a better understanding of the effectiveness of a remedial technology and on providing rapid, low-cost alternatives to traditional performance evaluations, such as soil and groundwater sampling. Research and development activities at laboratory-, bench-, and field-scale will be considered, but work does not necessarily have to culminate in a field-scale effort.

BACKGROUND: Although DoD facilities have numerous types of contaminants, chlorinated solvents are by far the most prevalent, particularly trichloroethene (TCE) and tetrachloroethene (PCE), but related compounds such as trichloroethane (TCA), vinyl chloride (VC), dichloroethenes (DCE), and carbon tetrachloride (CT) also represent significant concerns. These chlorinated aliphatic hydrocarbons (CAHs) also remain among the most difficult to remediate, despite several years of research and development.

A number of technologies are currently in use for remediation of chlorinated solvent-contaminated sites. However, while the current selection of remedial technologies is probably sufficient, it is not well understood how well the technologies work or how they can be optimized, particularly under varying site conditions. Monitoring of the performance of remedial technologies has traditionally relied on relatively expensive and time-intensive sampling techniques, with rapid analysis often not available or possible. Consequently, system performance evaluations may be inadequate and can contribute to failure to achieve remedial goals by providing a false indication that the system is functioning. Development of rapid, cost-effective diagnostic procedures for evaluating system performance will likely result in more rapid optimization of system performance and ultimately more rapid and cost-effective achievement of remedial goals.

The performance of existing and developing remediation technologies needs to be evaluated with diagnostic procedures, both at the pilot scale and in field-scale implementations. For a number of remediation technologies, this evaluation may require developing new diagnostic procedures. It also requires better technical guidance on using diagnostic procedures to improve our ability to determine technology-limited remedial endpoints at chlorinated solvent-contaminated sites. An example of this approach involving SERDP and ESTCP has been the development of technical guidance and diagnostic procedures for in situ air sparging, which has helped this technology evolve from being a "hit and miss" approach to a more robust remediation technology.

CORE STATEMENT OF NEED FOR FY 2003
CLEANUP – CUSON-03-03

ASSESSMENT OF LONG-TERM SUSTAINABILITY OF MONITORED NATURAL ATTENUATION OF CHLORINATED SOLVENTS

OBJECTIVE: The objective of this SON is to seek applied studies to develop a better understanding of the long-term sustainability of natural attenuation of chlorinated solvents such as tetrachloroethene (PCE) and trichloroethene (TCE) and their breakdown products (dichloroethene [DCE] and vinyl chloride [VC]). Guidance on appropriate characterization methods and development of accurate predictive models are needed as well as effective evaluation and assessment of all natural attenuation processes that might occur, including reductive dehalogenation, aerobic biodegradation, dilution, dispersion, sorption, volatilization, and abiotic degradation. This work should lead to development of a guidance document and tools for assessing the potential for long-term sustainability of natural attenuation of chlorinated aliphatic hydrocarbons at a given site.

Proposers should demonstrate how their effort will complement, interact, or build upon previous and current research and development activities involving the biotransformation of chlorinated aliphatic compounds in the environment. Proposers should also demonstrate how the anticipated results would assist practitioners to better assess and possibly reduce human and environmental risk associated with chlorinated aliphatic soil and groundwater contamination and assist in designing cost effective remediation approaches. Results from this work will provide the practical understanding of the long-term sustainability of natural attenuation of chlorinated aliphatic hydrocarbons under various field conditions. This understanding will allow engineers to more accurately predict the time required to attain environmentally acceptable endpoints through natural attenuation and their sustainability.

BACKGROUND: Monitored natural attenuation has become widely used for petroleum sites, and is becoming more common for chlorinated aliphatic hydrocarbons. There is little doubt that monitored natural attenuation will be used for many DoD sites, either after more aggressive treatment or in some cases as the sole remedy. It is economically attractive when it works, and further, monitored natural attenuation may be the only practical alternative for many plumes that are very large in size and/or extend under structures or urban areas. However, there are significant questions regarding the conditions under which monitored natural attenuation can be used with confidence, particularly when the attenuation processes are relatively slow. The most critical need is to assess the long-term sustainability of monitored natural attenuation.

Reductive dechlorination is the most important attenuation process, and appears to be occurring at many sites. However, the process will have to continue to be effective over several decades in many cases, and such long-term performance requires a continual sufficient supply of electron donors and/or nutrients. There is little long-term data available to evaluate the long-term efficacy of monitored natural attenuation under different environmental conditions. Guidance on appropriate characterization methods and development of accurate predictive models are needed before we can use monitored natural attenuation with confidence at a specific site.

In addition, many chlorinated aliphatic hydrocarbon plumes are under aerobic conditions, so that reductive dechlorination will not be a major natural attenuation process. However, other natural attenuation mechanisms may occur, including dilution, dispersion, sorption, volatilization, abiotic degradation, and aerobic biodegradation. These processes may occur at very slow rates, but still at rates that can be significant in the long term. An effective evaluation and assessment of these other natural attenuation processes that might occur at these sites would (1) provide DoD with realistic expectations of what these mechanisms might be able to accomplish in the long term and (2) provide evidence that can be used to convince the regulators and the public that long-term natural attenuation is the best approach for these sites.

CORE STATEMENT OF NEED FOR FY 2003
CLEANUP – CUSON-03-04

IN SITU SEQUESTRATION ENHANCEMENT AND ENGINEERED BIOAVAILABILITY REDUCTION OF METALS IN SOILS

OBJECTIVE: The objective of this Statement of Need (SON) is to seek fundamental and applied studies to develop a better understanding of the enhancement of in situ sequestration and/or engineered reduction of metals bioavailability in soils. This SON seeks to increase the knowledge base regarding the mechanisms by which different soil amendments or other approaches alter the form of metals in soil and the resulting impacts on bioavailability. Mechanisms may vary by soil type, soil amendment, and/or remedial approach, but may include precipitation, humification, sorption, ion exchange, chelation, and redox transformations. Chemical alterations of the metals should be long-lasting, preferably permanent.

The research funded under this SON should address any or all of the metals that drive risk-based remedial action at DoD facilities including lead, arsenic, chromium, and cadmium. Proposals should focus on traditional soils contaminated with metals, not sediments. In addition, proposals that concentrate on solidification processes will not be considered. Research and development activities at laboratory-scale, bench-scale, and field studies will be considered, but work does not necessarily have to culminate in a field-scale effort. Proposers should demonstrate how their effort will complement, interact, or build upon previous and current research and development activities. The proposed work should lead to development of a greater understanding of control of sequestration and/or reduced bioavailability processes that will result in long-term stability of DoD metals of concern in soils.

BACKGROUND: There are nearly 17,000 sites on DoD installations potentially requiring environmental cleanup. The challenges facing those involved in cleanup include distinguishing those sites that pose significant environmental risks from those that pose little risk, prioritizing contaminated sites by the degree of risk posed, quantifying the risks at each site, and developing remedial actions and cleanup goals where appropriate.

During the last 30 years, the science of environmental risk assessment and understanding of the fundamentals of the fate of metals in soils and the environment have greatly improved. Many areas of research on metals have provided information to build this fuller understanding, including metals in fertilizers, pesticides, manures, limestones, and biosolids used in agriculture; paint; automotive exhausts; smelter and other stack emissions and slags; mine wastes; fly ash; flue gas desulfurization residues; dredged materials; and geological (geogenic) sources of soil metal enrichment. Although each metal in each source could have unique properties in each soil and each plant, general principles have been established for the fate and potential effects of metals in different sources applied to soils. Knowledge of the risks from soil metals has come from toxicological studies, epidemiological studies, agricultural and soil chemical studies, and studies of livestock and wildlife.

Efforts to understand the use of soil amendments for enhancing sequestration of metals has increased in the past few years. Ideally, such amendments should act rapidly following application so as to reduce or prevent leaching, plant uptake, and bioavailability. Soil amendments that have little economic cost are preferred to more expensive materials. Significant work remains to be conducted to fully understand the control of mechanisms that alter metal speciation in soil. The ability to reduce the human and ecologic risk associated with metal-contaminated soils through enhanced control of natural processes such as sequestration and bioavailability would result in significant remedial cost savings to the DoD.

SUPPLEMENTAL STATEMENT OF NEED FOR FY 2002
COMPLIANCE – CPSON-02-04

ADVANCED ACOUSTIC MODELS FOR MILITARY AIRCRAFT NOISE PROPAGATION AND IMPACT ASSESSMENTS

OBJECTIVE: The objective of this Statement of Need is to provide an improved predictive capability to estimate noise propagation from military aircraft operations at military facilities and calculate the footprints used for determining the impact of noise emitted on local and regional communities. This objective is motivated by the fact that many DoD aircraft are operated in areas where the operations have the potential to impact the underlying and/or surrounding communities. In addition, DoD aircraft exhibit performance characteristics that are realized by exceptionally high power to weight ratios. The techniques used to achieve the exceptional speeds and power outputs also contribute to acoustic production. The final objective is to create a validated model for high performance aircraft noise to provide the legally defensible foundation required for DoD environmental documentation. Proposed work should exploit advanced non-linear acoustic propagation science, enhance existing or develop new acoustic models, develop new 3-dimensional acoustic source directivity measuring techniques for both ground and airborne sources, validate the new acoustic models, and develop dynamic data visualization systems to aid impact assessments.

BACKGROUND: In its June 2000 report, the Joint Strike Fighter (JSF) Overarching Integrated Product Team raised concerns over potential emissions and noise regulations threatening to impact future JSF basing considerations. The report noted that several groups had been convened to begin addressing these concerns, including an Air Force-chaired (SAF/MIQ) Working Level Integrated Product Team (WIPT) to examine the shortcomings in existing community noise models used for characterizing noise produced by high performance engines. The SAF/MIQ-chaired WIPT found limitations for the new generation of high performance aircraft in existing community noise models. These limitations are expected to apply to all newer, high performance aircraft and will unnecessarily cause reductions in available air space for training and operations without a refined and validated community noise model. An improved noise model is a technology and developmental need, critical to providing the information needed to support public debate and protect future use of air space, flight operations, and weapon system basing.

Models, together with observations, play a vital role in the study of physical systems responsible for the emission, propagation, and reception of acoustic energy. Special emphasis should be placed on three areas that are not included in current noise models:

1. Non-linear propagation - Non-linear effects are observed in the propagation of high intensity (above 135-140 dB) sources. The non-linear effects are seen in a shift of low frequency energy into higher frequencies. The absorption of sound in air is greater at higher frequencies. The non-linear effects are greatest near the source and are thought by some experts to reduce to a linear approximation in the far-field. Other experts contend that the non-linear effects are continued in the far-field. Recent measurements on high performance aircraft have indicated the probability of non-linear effects at what is thought to be the far-field.

2. 3-Dimensional directivity - The effects of source directivity on the resulting noise footprint are extensive. Modifications to data collection procedures in addition to changes to acoustic models are required to accurately predict noise footprints and potential impacts from aircraft employing non-round and/or thrust vectoring nozzles.

3. Dynamic visualization - The addition of non-linear propagation and 3-dimensional directivity to existing models will result in a nearly exponential increase to the volume of the data output by the model. Visualization techniques are required to adequately access and potentially mitigate the impact of the acoustic fields.

SUPPLEMENTAL STATEMENT OF NEED FOR FY 2002
COMPLIANCE – CPSON-02-05

LAND MANAGEMENT IMPACTS ON THE ENVIRONMENTAL FATE AND TRANSPORT OF ENERGETIC MATERIALS ON DOD TEST AND TRAINING RANGES

OBJECTIVE: The objective of this Statement of Need is to investigate and assess the impact of land management practices on the environmental fate and transport of energetic materials that may be released due to live fire activities on DoD terrestrial test and training ranges. The land management actions of interest include activities such as burning, thinning, planting and seeding, or other restorative and mitigation measures used for range sustainability. The primary energetic compounds of interest are RDX, HMX, TNT, DNT and their breakdown products. The primary migration pathways of concern include surface run-off and subsurface migration/leaching to groundwater. Applied laboratory research and field studies are of interest.

The goal of the proposed work is to increase our understanding of the impacts of land management activities on the transport and fate of energetic residues deposited on our ranges so as to enable DoD to more effectively manage ranges in a sustainable fashion. Results from this research will aid in developing long-term range management strategies to minimize or eliminate the potential for energetic contaminants to adversely effect environmental receptors of concern.

BACKGROUND: There exists a growing concern about the potential for military training activities leading to groundwater and surface water contamination on DOD ranges. One example of this situation exists at the Massachusetts Military Reservation (MMR). Military and law enforcement training has been conducted for over forty years in the Training Range and Impact Area, which encompass almost 14,000 acres at MMR. The Training Range and Impact Area lie directly over the Cape Cod Aquifer, which has been designated as a sole drinking water source for Cape Cod. The detection of energetic compounds in the groundwater beneath the Training Range and Impact Area demonstrates the potential for military training activities to cause groundwater contamination.

Military bases conduct various land management practices (such as controlled burning, thinning, planting and seeding). These activities are conducted independent of their potential detrimental or beneficial impact on the potential of energetic material to migrate and impact environmental and human receptors. Changes in the timing, extent or nature of these management actions could be used to more effectively manage DoD ranges and lessen the potential impact of energetic residues that enter the environment through test and training activities.

CORE STATEMENT OF NEED FOR FY 2003
COMPLIANCE – CPSON-03-01

CHARACTERIZATION OF OFF-ROAD DIESEL VEHICLE EMISSION OF CRITERIA AIR POLLUTANTS

OBJECTIVE: The objective of this Statement of Need (SON) is to solicit proposals to develop sampling methods and characterize emissions of criteria air pollutants from DoD-unique diesel engines, specifically from off-road diesel vehicles and diesel generators. These pollutants may include fine particulate matter (PM2.5), nitrogen oxide and nitrogen dioxide (NOx), and sulfur oxides (SOx). Proposers should be expected to develop source- and fuel-specific emission factors for these criteria air pollutants that will allow DoD users to satisfy local and state regulatory and permit needs as a function of engine types, fuel types (JP-8, diesel, biodiesel, fuels with additives, etc), and use patterns. This work may require the use of innovative sampling methods, adaptation of stationary sampling methods to mobile off-road vehicles, and use of innovative sample analysis techniques. Proposers are expected to understand emissions as a function of engine-, fuel-, and use-specific factors that might allow for recommendations on the minimization of emissions.

State and Federal regulators are developing emissions inventories of NOx and PM2.5. Inventories of NOx and PM2.5 emissions are needed for the development of State Implementation Plans to control emissions of these criteria air pollutants. The impact on DoD activities as a result of the promulgation of EPA regulations in non-attainment areas or for source-specific emission limits could be substantial. The results of this work will provide accurate estimates of the DoD sources of these criteria air pollutants from off-road and stationary diesel engines.

BACKGROUND: Diesel exhaust is a complex mixture of gases and fine particles, which contains more than 40 substances that EPA considers either hazardous or criteria air pollutants. PM has significant non-cancer effects (mortality) which are the basis of the National Ambient Air Quality Standards. Diesel PM is now designated a likely human carcinogen. The non-cancer and possible cancer impacts are the basis of EPA's stringent new diesel regulations. EPA has proposed new, more restrictive standards for criteria pollutants in vehicle model years 2004 and 2007, which are scheduled to be made final shortly. In August 1999, the California Air Resources Board (CARB) listed diesel exhaust particulate matter as a toxic air contaminant and a human carcinogen, which may have significant impacts on the DoD bases in California. A similar push is expected from the Federal sector. And in November 1999, regulators in Southern California approved their report noting that particulates in diesel exhaust make up 70% of the cancer risk from air pollution in the region. [Excerpts from Environmental Science & Technology, Feb. 1, 2000, 71A]

The impact on the DoD of promulgation of EPA regulations in non-attainment areas (e.g. PM, ozone, ambient air toxics) or for source-specific air pollutant emission limits could be substantial, even though provisions are made for some exemptions of DoD equipment from federal emission standards. The DoD has extensive numbers and types of off-road diesel vehicles, and relies on their unimpeded use for operations, training, and mission readiness. Therefore, this Statement of Need calls for development of accurate, comprehensive data on off-road, DoD diesel engine emissions from off-road diesel DoD vehicles for NOx, PM2.5, and SOx. This likely will require source assessment via a DoD diesel inventory, the development of on-source sampling methods for emissions-significant DoD diesels, use of ambient and path-length monitoring methods, and verification of laboratory emissions measurements with on-board, real-time, operational duty cycle measurements. An emission factor is defined by EPA as a representative value that attempts to relate the quantity of a pollutant released to the atmosphere with an activity associated with the release of that pollutant. They are expressed as a mass of pollutant per a unit volume, distance, or duration of an activity emitting the pollutant. Emission factors developed under this SON should be statistically representative of the activities of concern with quantifiable estimates of their uncertainty.

CORE STATEMENT OF NEED FOR FY 2003
COMPLIANCE – CPSON-03-02

CHARACTERIZING & MONITORING NON-POINT SOURCE RUNOFF FROM MILITARY RANGES AND IDENTIFYING THEIR IMPACTS TO RECEIVING WATER BODIES

OBJECTIVE: The objectives of this SON are to provide tools and/or data to both characterize and monitor non-point source runoff resulting from military activities on DoD training and testing ranges and to identify the impact of these sources on receiving waters. Anticipated products resulting from proposals responding to this SON include (1) identification of military activities within training and testing ranges that are non-point sources of pollutants, (2) development of tools to assess and diagnose the impairment of aquatic systems from potential military-specific, non-point sources of pollutants, (3) development of field-portable technologies to provide real-time monitoring (including both temporal and spatial variability) of the quantity and quality of non-point source runoff from DoD installations, and (4) data and technologies that advance the state-of-knowledge of the development of total maximum daily loads (TMDLs), such as GIS technologies to model the contribution of DoD sources of non-point pollution. Efforts proposed toward this SON must address the diversity of non-point source runoff and be able to distinguish military-specific sources from other sources of runoff pollution. To the extent practicable, the results of this work should be applicable to transition to multiple military sites on a variety of scales.

BACKGROUND: Non-point source runoff pollution is the diffuse runoff of pollutants from land surfaces during wet weather events and other discharges and is recognized as a significant contributor to water quality problems, contributing as much as 50% of the nation's water pollution. Pollutants in non-point source runoff vary widely and include eroded sediments, heavy metals, pesticides, and oil and grease. Activities at DoD installations, such as training/testing, the maintenance and operation of military vehicles and aircraft, runoff from roads and bridges, stormwater runoff, and sewer overflows are potential sources of non-point source pollution and may potentially impact nearby surface waters. By their very nature, non-point pollutant sources are diverse, diffuse, site-specific, and intermittent, making them difficult to characterize and control.

The TMDL process is a course of action proposed by EPA under the Clean Water Act Section 303(d) by which impaired waters are restored by setting limits on the discharge of pollutants into surface waters. Currently, the recommended scale of analysis and implementation is at the watershed level. Much progress has been made recently in addressing the TMDL process. EPA has identified several trends emerging from research efforts addressing the definition and management of TMDLs. These trends or challenges include: (1) a shift in focus from point source discharges as the major source of pollutants to non-point sources, (2) an increased awareness of the importance of landscape- and watershed-scale processes activities, (3) an increase in the awareness of the role of atmospheric deposition and multimedia sources as determinants of water quality, (4) an increased awareness of the role of habitat alterations as a cause of aquatic ecosystem impairment, and (5) an increasing use of biological indicators and metrics as the preferred method for determining the condition of aquatic ecosystems.

Through implementation of the CWA, it is the responsibility of Federal land management agencies, to protect and restore the quality of public waters under their jurisdiction. DoD will need to take measures to prevent excessive discharges of non-point source pollution or be faced with a violation of the new TMDL and existing NPDES regulations. Specifically, DoD needs to (1) determine if DoD training ranges are located within watersheds having designated impaired waters, (2) determine if those impaired waters either upstream or outside the range are affecting waters within the range, (3) develop monitoring programs at ranges, and (4) continue to work with other stakeholders to improve the science and technology to control non-point source pollution and to improve estimates of the magnitude and sources of non-point source pollution.

SUPPLEMENTAL STATEMENT OF NEED FOR FY 2002
CONSERVATION – CSSON-02-05

THE IMPACT OF MILITARY TRAINING ACTIVITIES, LAND MANAGEMENT ACTIONS, AND SPECIES/HABITAT SENSITIVITIES ON TERRESTRIAL THREATENED AND ENDANGERED SPECIES

OBJECTIVE: The objective of this Statement of Need is to develop or apply methods and technologies that evaluate the effects of and possible interrelationships between military operations (training activities and land management actions) and species/habitat sensitivities on the occurrence and vitality of threatened or endangered species (TES). Specifically, the DoD needs to better characterize the impact from military operations on TES and/or their habitats by quantifying (1) disturbance related to military training activities resulting in the generation of noise, contamination by energetic materials, sedimentation/erosion, and obscurants (dust, smoke, etc.); (2) disturbance (positive and/or negative) related to land management actions such as burning, thinning, planting and seeding, or other restorative and mitigation measures; and (3) species/habitat sensitivities that control individual survivorship, fecundity, life-cycle disruption, food chain alteration, and behaviors.

Efforts proposed under this Statement of Need should result in increased ability of land managers to understand the implications of military land disturbances and species/habitat sensitivity as it relates to the management of TES. The knowledge and/or tools that result should support a process of adaptive management on military installations in order to sustain both military training activities and compliance with ESA requirements.

BACKGROUND: Federal agencies, including the Department of Defense, are required to comply with federal statues dealing with threatened and endangered species. Most notable of these laws is the Endangered Species Act of 1973, as amended, which, in addition to establishing a national policy to conserve threatened and endangered species, mandates that federal agencies take no action that is likely to compromise species covered under the Act. Many threatened and endangered animal species are inherently hard to observe (nocturnal, limited range, low density, mobile, burrow dwelling, etc.) and basic behavioral (i.e., non-disturbed) patterns are not understood for many species.

Mission critical military training and testing has been impacted by known, unknown, or potential impacts on threatened and endangered species. In many cases, insufficient information and/or inadequate technology or techniques are available to identify or establish if and/or what effects or impacts may exist as a result of military training activities. Specific military training activities of concern have been identified and include those that include weapons and aircraft noise and/or obscurant smoke, or result in significant land or other disturbance such as that which may be attributable to large tracked vehicles, munitions testing, or other activities. In addition, while possibly but not necessarily related to military training, contaminants (e.g. metals, petroleum hydrocarbons, etc.) are also a matter of concern.

Traditionally, DoD addressed TES issues as a single cause and effect type of reaction. However, efforts are being made to integrate the efforts of land management, ecosystem sensitivities and military training demands in a more systematic or holistic approach across the entire installation and, when possible, across the ecoregion. Problematic demands of sustaining the optimum stewardship of DoD resources to maintain mission readiness require creating useful linkages between military activities, ecology, policy processes, and resource management. Through an understanding of sustainability, installations are embracing the concept of adaptive management as a means to integrate the demands of military training and resource management by monitoring the impacts of both types of activities on key species and/or ecosystem indicators that identify the integrity of the ecosystem. Consequently, the need exists to quantify the impact of land management activities on T&E species.

CORE STATEMENT OF NEED FOR FY 2003
CONSERVATION – CSSON-03-01

THE IMPACT OF MILITARY TRAINING ACTIVITIES, LAND MANAGEMENT ACTIONS AND SPECIES/HABITAT SENSITIVITIES ON AQUATIC THREATENED AND ENDANGERED SPECIES

OBJECTIVE: The objective of this Statement of Need (SON) is to develop or apply methods and technologies that evaluate the effects of and possible interrelationships between military operations (training activities and land management actions) and species/habitat sensitivities on the occurrence and vitality of aquatic threatened or endangered species (TES). Specifically, the DoD needs to better characterize the impact from military operations on aquatic TES (both freshwater and marine) and/or their habitats (e.g., oceans, benthic communities, coral reefs, estuaries, lakes, ponds, and streams) by quantifying (1) disturbance of aquatic TES and their habitats related to military training activities resulting in the generation of noise, contamination by energetic materials and sedimentation/erosion; (2) disturbance of TES and their habitats (positive and/or negative) related to land management actions such as burning, thinning, planting and seeding, or other restorative and mitigation measures such as shore management and beach erosion control; and (3) species / habitat sensitivities that control individual survivorship, fecundity, life-cycle disruption, food chain alteration, and behaviors.

Efforts proposed under this Statement of Need should result in an increased ability of land managers to understand the implications of military land and shore disturbances and species/habitat sensitivity as it relates to the management of aquatic TES. The knowledge and/or tools that result should support a process of adaptive management on military installations in order to sustain both military training activities and compliance with ESA requirements. It is not the purpose of this Statement of Need to study marine mammals. Studies relating to these animals are covered by other research efforts.

BACKGROUND: Federal agencies, including the Department of Defense, are required to comply with federal statues dealing with threatened and endangered species. Most notable of these laws is the Endangered Species Act of 1973, as amended, which in addition to establishing a national policy to conserve threatened and endangered species, mandates that federal agencies take no action that is likely to compromise species covered under the Act. Mission critical military training and testing has been impacted by known, unknown, or potential impacts on aquatic threatened and endangered species. In many cases, insufficient information and/or inadequate technology or techniques are available to identify or establish if and/or what effects or impacts may exist as a result of military training activities. Specific military training activities of concern have been identified and include those that include weapons and aircraft noise, or result in significant land or other disturbance such as that which may be attributable to amphibious vehicles and boats, munitions testing, or other activities. In addition, while possibly but not necessarily related to military training, chemical contaminants (e.g. metals, petroleum hydrocarbons, etc.) are also a matter of concern.

Traditionally, DoD addressed TES issues as a single cause and effect relationship. However, efforts are being made to integrate the efforts of land and aquatic management, ecosystem sensitivities and military training demands in a more systematic or holistic approach across the entire installation and when possible across the ecoregion. Problematic demands of sustaining the optimum stewardship of DoD resources to maintain mission readiness require creating useful linkages between military activities, ecology, policy processes, and resource management. Through an understanding of sustainability, installations are embracing the concept of adaptive management as a means to integrate the demands of military training and resource management by monitoring the impacts of both types of activities on key species and/or ecosystem indicators that identify the integrity of the ecosystem. Consequently, the need exists to quantify the impact of land and water management activities on aquatic T&E species.

CORE STATEMENT OF NEED FOR FY 2003
CONSERVATION – CSSON-03-02

ASSESSMENT OF BENTHIC COMMUNITIES FOR THE DEPARTMENT OF DEFENSE

OBJECTIVE: The objective of this Statement of Need (SON) is to develop advanced technologies to map and assess coral reef communities and other benthic marine habitats for the Department of Defense (DoD). Specifically, the objectives are as follows:

a. Develop advanced technologies to assess DoD coral reef communities. The instrumentation or technologies should be capable of rapid ecological assessment procedures and integrated with GIS. Part of this objective is the development of technologies for permanent underwater monitoring stations for coral reef areas under the control of DoD. These monitoring stations should be capable of measuring general biological, physical and chemical parameters to provide ongoing biological and environmental information about the area over time. Data retrieval should be available upon request. This monitoring stations should be capable of sustained operations with maintenance for periods of months.

b. Develop advanced technologies for fine-grained mapping and assessment of specific benthic areas. This system may be highly mobile and mounted on a mobile platform, Diver Propulsion Vehicle (DPV) or a Remote Operated Vehicle (ROV). Alternatively, a system may be a fixed platform and capable of monitoring key biological and physical environmental variables that are key indicators of reef community viability and health. The system must be able to operate in and around aquatic communities in full or semi-autonomous modes. A visual recognition system and specialized environmental sensors should be integrated into the system for biological/physical/chemical measurements. It should also possess an integrated precise navigation / geo-location system to map coral reef communities. This system will be used to provide comprehensive and detailed assessment information on selected coral reef communities to include ecosystem health and possible biological species identification.

BACKGROUND: Global concern regarding the rapid degradation of the marine environment is growing. The U.S. and host countries are concerned and actively involved with the protection of marine resources. In response to the rapid deterioration of coral reefs worldwide, Executive Order 13089 on Coral Reef Protection directs Federal agencies to study, restore, and conserve U.S. coral reef ecosystems. It also established the Coral Reef Task Force (CRTF), comprised of 11 Federal agencies and the governors of 7 states, territories or commonwealths with responsibilities for coral reefs (see www.coralreef.gov). The CRTF was directed to oversee Federal agency implementation of EO 13089 and to implement initiatives in the following areas: coral reef mapping and monitoring; research on causes of reef degradation; conservation, mitigation and restoration measures; and international cooperation strategies. In March 2000, the CRTF published The National Action Plan to Conserve Coral Reefs, a comprehensive document outlining goals, objectives, strategies, and priority actions to prevent the further decline of coral reefs.

A major thrust in both the action plan developed under EO 13089 and the Strategy is a mapping and inventory initiative of all U.S. coral reef ecosystems. The assessment and monitoring initiative includes conducting rapid assessment and inventories, monitoring of coral, fish, and other resources, and evaluation of water and substrate quality. To implement DoD's responsibilities under the CRTF and comply with the CRCA, mapping and inventory information must be gathered on the military's coral reef resources. As a member of the CRTF, it is DoD's role and duty to conduct these activities. Moreover, DODI 4715.3, directs DoD to inventory biologically or geographically significant or sensitive natural resources. This information is also necessary for preparation of integrated natural resources management plans required by the Sikes Act Improvement Act, 16 USC §670a - o.

CORE STATEMENT OF NEED FOR FY 2003
CONSERVATION – CSSON-03-03

ESTUARINE ECOSYSTEM MANAGEMENT AND RESTORATION

OBJECTIVE: The objective of this statement of need (SON) is to solicit proposals to (1) evaluate the environmental impacts of military activities on estuarine ecosystems and (2) develop restoration/enhancement methods and conservation management techniques to minimize these impacts and sustain the beneficial qualities of estuarine ecosystems within Department of Defense (DoD) installations. Proposals responding to this SON should address some or all of the specific tasks:

1. Develop fundamental knowledge of important physical, chemical, and biological estuarine processes relevant for management or restoration activities. Ecological conditions necessary for sustaining the beneficial qualities of estuaries such as erosion/sediment transport control, nutrient/toxic filtration, and biodiversity should be identified and quantified. Knowledge of baseline estuarine conditions will enable the quantification and assessment of the impacts DoD activities on estuarine environments.

2. Design and conduct field studies that result in increased understanding of the impacts of various military training and other DoD activities on estuarine ecosystem components and functions. A fundamental knowledge of how estuarine ecosystems function and respond to stresses from military activities impacting terrestrial and aquatic components is required for developing effective methods of restoring, enhancing, and/or maintaining these systems.

3. Improve existing, or develop new restoration/enhancement techniques and ecosystem management strategies for sustaining estuarine ecosystems that are impacted by various military training and other activities on Department of Defense installations. These techniques and strategies should take a "systems" approach and account for the integral relationship of estuarine ecosystems with their surrounding terrestrial, aquatic, and oceanic environments.

BACKGROUND: Estuaries are bodies of water, such as bays, lagoons, or sloughs in which where fresh water from rivers and streams mix with saltwater. These important coastal habitats are spawning grounds and nurseries for at least two-thirds of the nation's commercial fish and shellfish. The wetlands associated with estuaries buffer coastal lands from flooding. Estuarine ecosystems are also of significant socioeconomic, recreational, and aesthetic value to humans.

Although estuarine ecosystems typically comprise a relatively small proportion of the total landscape, they are among the most diverse, dynamic, and complex biological systems on earth, and contribute significantly to regional biodiversity. The availability of water to vegetation, frequently in combination with deep soils, promotes plant biomass and a rich and structurally diverse plant community that provides a wide variety of habitats for a large diversity of both terrestrial and aquatic animals.

Estuarine areas are sensitive to human-induced disturbances. Military installations present both unique and common stressors that impact ecosystem sustainability. The cumulative effects of such disturbances can result in a significant reduction of ecosystem functionality and associated benefits.

SUPPLEMENTAL STATEMENT OF NEED FOR FY 2002
POLLUTION PREVENTION – PPSON-02-07

ENVIRONMENTALLY ACCEPTABLE SMALL, ELECTRO-EXPLOSIVE DEVICES FOR MEDIUM CALIBER MUNITIONS

OBJECTIVE: The objective of this Statement of Need is to develop environmentally benign, small, electro-explosive devices (EEDs) (detonators). These small EEDs (detonators) are to be sized such that they will be compatible (volume, weight and power) with the newest fuzes being developed for medium caliber (20-60mm) ammunition and have sufficient output energy to initiate lead and main charges containing "insensitive" explosives. These detonators currently use lead styphnate, lead azide and HMX in their construction and all of these are considered to be hazardous/toxic materials. This project is to identify an alternate chemistry to eliminate or minimize their use. The new EEDs must also provide the same relative level of affordability as current designs (depending upon quantity produced, \$3-9 per EED). The development of environmentally benign small EEDs (detonators) will result in the significant reduction of the release of hazardous materials during manufacture, use and demilitarization of medium caliber fuzes.

BACKGROUND: Current medium caliber high explosive munitions are functioned by initiating an impact sensitive (stab) detonator. This requires the projectile to strike an object with sufficient force to rapidly push a firing pin into an initiating mix. The next generation of fuzes for medium caliber rounds is seeking to selectively function the round in at least three modes; (1) at a pre-determined location in space without impact, (2) upon impact with the target but within the protective covering of the target or (3) immediately upon impact with the target. To have this flexibility in the design, the fuze must have a selection of the functioning mode prior to shot start and then a method of initiating the round when the detonation conditions are satisfied. The current impact initiated detonators require a relatively large impact energy to initiate, an energy that would have to be created by an onboard mechanism in the case of no target impact. Weight and space constraints prohibit the incorporation of this type of device. Instead, small EEDs are being utilized in these new design concepts to accomplish this initiation. With a small EED, the detonator can be functioned electrically, regardless of fuze functioning mode. The only available EEDs that will meet the functional requirements are the M100 detonator and variants of the M100 (e.g. PA537, etc). The M100 no fire requirement is the energy discharged from a 100 m| capacitor charged to 0.7 volt potential. The 99% reliability with 99% confidence all fire requirement is dependent upon the circuit design. The all fire circuit range for the M100 is a 0.1m| capacitor charged to a 30.4 volt potential (462 ergs) up to a 100m| capacitor charged to a 1.7 volt potential (1445 ergs).

The M100 and its variants are all functioned by electrically initiating (bridge wire) a spot charge of Lead Styphnate that outputs into a transfer charge of Lead Azide. The lead charge consists of 0.0008 grams of pure Lead Styphnate placed on a bridge wire lead. The bridge wire is then placed into 0.014 grams of pure Special Purpose Lead Azide. The Lead Azide then detonates a base charge of 0.016 grams of Grade B, Class 3 HMX. The variations on the M100 achieve smaller lengths by having less or no base charge.

SUPPLEMENTAL STATEMENT OF NEED FOR FY 2002
POLLUTION PREVENTION – PPSON-02-08

ENVIRONMENTALLY ACCEPTABLE INCENDIARY COMPOSITIONS FOR MEDIUM CALIBER AMMUNITION

OBJECTIVE: The objective of this Statement of Need is to develop alternative chemistries to eliminate the use of toxic, heavy metals and volatile organic chemicals (VOC) that are currently used in the manufacture of incendiary compositions for medium caliber (20mm - 60mm) ammunition applications. Proposals shall address technologies, methods, or processes that (1) develop or evaluate the use of alternative fuels and/or oxidizers that are environmentally benign and (2) eliminate or minimize the use of VOCs in the manufacturing process of incendiary materials.

New compositions shall provide equivalent or increased levels of performance compared to current formulations. The development of environmentally benign incendiary compositions will result in a significant reduction in the release of hazardous/toxic materials and VOCs during manufacture and use of incendiaries in medium caliber munitions.

BACKGROUND: Incendiary compositions are physical mixtures of finely powdered compounds and elements. The main constituents are (1) oxidizing agents such as chlorates, perchlorates, nitrates, peroxides, oxides, and chromates; (2) fuels such as powdered metals, silicon, boron, sulfur, hydrides, and sugar; and (3) binders and color intensifiers, which are usually organic compounds. These include highly chlorinated organic compounds such as hexachloroethane, hexachlorobenzene, polyvinylchloride, and dechlorane. The binding agents, consisting of resins, waxes, and polymers, are added to prevent segregation and to obtain more uniformly blended compositions. In addition, they serve to make finely divided particles adhere to each other when compressed and help to obtain maximum burning efficiency. Burning rates are exceptionally important in applications utilizing incendiaries as initiating explosives, replacing mechanical fuzing and providing an inherent delay. When in contact with a fuel such as finely powdered metals of magnesium, magnesium-aluminum alloys, and zirconium, the fueling agent acts as a vigorous oxidizing agent producing an exothermal chemical reaction resulting in the formation of its corresponding oxides and the evolution of significant heat and radiant energy. The incendiary material must not only produce hot particles and gases but must also be impact sensitive so as to reliably react on projectile target impact. While highly effective, the heavy metals such as barium, antimony, and lead have been identified as hazardous materials and should be eliminated from all ammunition with suitable replacements introduced. When ignited, these pyrotechnic mixtures readily undergo an exothermal reaction that generates considerable energy in a short period of time. The heat of reaction for one gram of pyrotechnic composition ranges from approximately 200 to 2500 calories per gram. The energy produced is released as heat and light with temperatures ranging from 1000 degrees C to 3500 degrees C.

Pyrotechnic incendiary compositions are also hazardous because of their toxicity and sensitivity. Barium nitrate and antimony sulfide are moderately poisonous materials that can irritate the mucous membranes and the skin producing dermatitis and eye, nose and ear irritation. When heated, the toxic fumes may produce gastrointestinal irritation. Safe disposal of pyrotechnic ingredients is a problem because of the flammable, explosive, or toxic nature of these materials. To minimize the problem, it is necessary to segregate wastes, with the ultimate disposal carried out in strict accordance with the local operating procedures for each laboratory or plant. Approximately 2500 pounds of antimony sulfide and barium nitrate waste are being generated in medium caliber ammunition annually requiring safe disposal. The proposed effort should reduce toxic emissions and minimize hazardous waste streams.

SUPPLEMENTAL STATEMENT OF NEED FOR FY 2002
POLLUTION PREVENTION – PPSON-02-09

PERCUSSION PRIMERS FOR MEDIUM CALIBER AMMUNITION

OBJECTIVE: The objective of this Statement of Need (SON) is to reduce or eliminate environmentally unacceptable materials used in the formulation or manufacture of percussion primers and ignition booster pellets for medium caliber (20mm to 60mm) military ammunition. Examples of environmentally unacceptable compounds currently used in percussion primers and boosters include heavy metals such as lead (Pb) and barium (Ba) and compounds such as antimony sulfide that are known to be carcinogenic and toxic. Proposals shall address technologies, methods, and processes that (1) result in alternative primer compositions that are environmentally benign and (2) provide comparable or increased levels of performance in accordance with the following military specifications: MIL-P-60942A (40mm), MIL-P-50603B (25mm), and MIL-P-46601B (20mm/30mm).

The development of environmentally friendly primers will reduce or eliminate range contamination; mitigate the long-term exposure effects on plant, wildlife, and water systems; and drastically curtail the use of toxic materials at the various 20mm to 60mm manufacturing facilities. It will also result in reduced safety risks and reductions in prolonged exposure of both user and production personnel to harmful levels of contaminants and combustion products that occur in the material handling and disposal of toxic materials during production, test and operational use of medium caliber primers. Economic benefits include reduced ammunition, training and production site cleanup costs.

BACKGROUND: Percussion primers are fitted into the center opening of the cartridge case assembly of medium caliber ammunition and, upon impact with the firing pin of the weapon system, are used to ignite the propelling charge of the 20mm-60mm cartridge(s), propelling the projectile out the barrel at a pre-determined muzzle velocity. It is therefore essential that such ignition be conducted within a minimum action time of 3 milliseconds at 70 degrees Fahrenheit. The cartridge shall have a minimal functional reliability rate of 97%. This need for both quickness and reliability is the reason why extremely sensitive primary explosive compositions are selected to perform this function. Some typical primer explosives are lead azide, lead styphnate, and NOL 130. Lead azide is widely used in military applications but is a sensitive and relatively hazardous substance having an impact sensitivity of 3 inches using a 2 kg weight; 10 cm using Bureau of Mines apparatus, and an electrostatic discharge sensitivity of 0.007 joules; lead styphnate is less hazardous to process than lead azide having an impact sensitivity of 3 inches using a 2 kg weight; 17 cm using Bureau of Mines apparatus with an electrostatic discharge sensitivity of 0.0009 joules and has extensive commercial uses. A fairly common composition that is used extensively in 40mm percussion primers is NOL 130 that has an impact sensitivity of 3.75 inches using a 2 kg weight and an electrostatic discharge sensitivity of 0.0022 - 0.0028 joules. This is a multi-component composition that is quite sensitive and is closely related to commercial initiating explosives used in percussion primers. Although highly effective, the heavy metals such as barium, antimony, and lead that are typically used in primer compositions have been identified as hazardous materials per EPA regulation 10 CFR, part 1910 and therefore should be eliminated and replaced.

Percussion primer compositions are considered hazardous because of their toxicity and sensitivity. Barium nitrate and antimony sulfide are moderately poisonous materials. Safe disposal of the primer compositions is difficult because of the sensitive, explosive, and toxic nature of these materials. To minimize this problem, it is necessary to segregate wastes, with the ultimate disposal carried out in strict accordance with local operating procedures for each laboratory or plant. Approximately 2500 pounds of antimony sulfide and barium nitrate waste are being generated in the production of medium caliber ammunition annually. This does not include the waste stream from the material production process itself. This program will reduce toxic emissions and minimize the hazardous waste streams.

CORE STATEMENT OF NEED FOR FY 2003
POLLUTION PREVENTION – PPSON-03-01

CHROMIUM-FREE COATING SYSTEMS FOR DOD APPLICATIONS

OBJECTIVE: The objective of this Statement of Need (SON) is to develop an environmentally benign (Cr-free, low Volatile Organic Compounds [VOCs], low Hazardous Air Pollutants [HAPs]) coating system for metal alloy structural components in DoD systems. Candidate applications include, but are not limited to, aircraft, ships and other watercraft, missiles and munitions and support equipment. The primary focus of this work should be on the corrosion protection capabilities of the system. However, other technical elements that must be integrated include, but are not limited to: cleaning or surface preparation treatments (such as conversion coatings), corrosion protection treatments (such as primers), and mission specific treatments (such as topcoats). Replacements for Chemical Agent Resistant Coating (CARC) systems are specifically excluded from this solicitation.

The proposal should include plans to measure the performance capabilities of the new coating in a systems' context as compared to the current coating system and not as an individual component. System performance shall meet or exceed that of the current systems. Ultimately, the results of this research may integrate various efforts in DoD and industry to find Cr-free coating components that lead to, or provide a scientifically based foundation for coatings and processes that: (1) do not use or produce hazardous toxic substances and reduces or eliminates VOCs and HAPs, (2) corrosion protection and other properties that meet or exceed performance levels of current products and processes, and (3) can be produced and maintained within the DoD operational framework without excessive cost.

BACKGROUND: Coatings are the primary corrosion control strategy used by the DoD. The Air Force alone documented the cost of corrosion maintenance to be $795,264,699 in FY96. The current corrosion control strategy in DoD relies on hexavalent chromium to protect the substrates of its legacy aircraft such as 2024 and 7075 series aluminum. Hexavalent chromium is a known human carcinogen that is strictly regulated. The U.S. Occupational Safety and Health Administration (OSHA) regulates the amount of hexavalent chromium to which workers can be exposed, and has proposed reducing the Permissible Exposure Limit (PEL) for hexavalent chromium from the current 50 micrograms per cubic meter (mg/m^3) to less than 1 mg/m^3. OSHA's proposed PEL would severely impact the use of hexavalent chromium throughout DoD. New coating technologies are required to preserve existing assets against corrosion losses and to minimize the potential for negative impacts on the environment

Over the past several years SERDP, DARPA and AFOSR among others have invested heavily in understanding corrosion protection by incumbent coating technologies based on the use of chromate inhibitors. This has resulted in a greater understanding of the origins of corrosion resistance provided by chromates and has suggested approaches for duplicating corrosion protection without use of hazardous chemical ingredients. Chrome elimination coatings efforts have shown that individual product performance is not always indicative of the integrated systems performance. As long as products are developed and tested as individual components, development efforts are likely to continue to fall short of the "chrome" standard. Developing corrosion protection schemes as a system and gauging system performance is imperative to future efforts due to potentially detrimental or enhancing chemical interactions between the systems' components. To date, no completely chromium-free coating system (pre-treatment, conversion coating, primer, and topcoat) has been demonstrated that meets all the performance, manufacturing, maintainability and cost requirements needed for DoD applications.

CORE STATEMENT OF NEED FOR FY 2003
POLLUTION PREVENTION – PPSON-03-02

ENVIRONMENTALLY INNOVATIVE TECHNOLOGIES FOR METAL PARTS CLEANING FOR ELECTROPLATING AND SURFACE FINISHING

OBJECTIVE: The objective of this Statement of Need (SON) is to develop affordable non-hazardous materials and processes for metal parts cleaning, while meeting unique component requirements for DoD systems. Specifically, the goal of this research is to develop qualified replacements for the chlorinated solvents used in cleaning metal parts. Areas of research may address both the development of alternative cleaning chemistries or the development of whole process alternatives for parts masking and cleaning. The development of a non-hazardous metal parts cleaning process for the preparation/masking of parts and metal surfaces for electroplating will result in reductions in the production and/or release of VOCs and the hazardous materials and waste streams associated with current practices.

BACKGROUND: DoD uses metal parts cleaning chemicals to remove wax from the masked areas of electroplated components. Some Depots have implemented cleaning alternatives such as citrus based solvents and other aqueous solutions. However these technologies are unable to remove the wax masking often applied to components prior to plating and they also have the potential to create embrittlement problems. Some flouro-based solvents are under consideration but their cost is prohibitive. As a result, many metal parts are still cleaned with perchloroethylene, CFC 113 or trichloroethane.

A typical part flow in a plating shop is as follows: Upon entering the production area, the part is cleaned, usually with an aqueous parts washer if one is available but often with a vapor degreaser. Tape and wax are applied to mask those portions of the part that will not be plated and the part is processed through the plating baths. After the final rinse, most of the wax is removed by immersing the part in a hot wax tank and the tape is manually removed. Finally, the part is placed in the vapor degreaser to remove all residual tape and wax contaminants. Problems associated with removing the wax include: engine part configuration (blind holes, small parts, complex geometries), the nature of the contaminant and the engine substrate (concerns with embrittlement, adhesion, etc.).

Under Section 612 of the Clean Air Act, EPA established the Significant New Alternatives Policy (SNAP) Program. SNAP's mandate is to identify alternatives to ozone depleting substances and to publish lists of acceptable and unacceptable substitutes. While perchloroethylene is an acceptable substitute for 1,1,1-trichloroethane (an ODS) for precision cleaning under SNAP, it is still a VOC, a hazardous air pollutant and a suspected human carcinogen. The federal government regulates the use and disposal of these toxic and hazardous substances with environmental and occupational safety and health laws, such as the Clean Air Act (CAA), the Clean Water Act (CWA), the Emergency Planning and Community Right-to-Know Act (EPCRA), and the Resource Conservation and Recovery Act (RCRA). In some cases, state and local governments use these laws as minimum standards for their stricter laws. If the DoD continues to use perchloroethylene it will make it difficult to meet hazardous materials reduction goals.

Responders are advised to carefully consider the relationship between the performance of proposed alternatives and the performance characteristics of specific metals and plating materials used in military system applications. Metals are generally selected for optimum fatigue, strength-to-weight ratio, and corrosion resistance characteristics. Plating materials are generally selected for wear, galvanic corrosion protection, and minimum degradation of the above metal substrate characteristics. Typical aluminum alloys include ASTM 2024, 2219, 2519, 5083, and 7075. Typical steels include low-carbon alloys such as ASTM 4130, and high-strength alloys including ASTM 4340, 300M, and Aeromet 100.

CORE STATEMENT OF NEED FOR FY 2003
POLLUTION PREVENTION – PPSON-03-03

ENVIRONMENTALLY ACCEPTABLE ALTERNATIVES FOR LIQUID SPRAY PAINT PRE-MIX COMPONENTS

OBJECTIVE: The objective of this Statement of Need (SON) is to develop an alternative approach to current two-part liquid paint mixtures used for wet-spray painting. Specifically, this effort seeks to develop new, environmentally benign coatings that can be stored in dry powder form and mixed with an environmentally benign liquid for application by wet-spray techniques. Use of these materials shall eliminate or reduce the release of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs) and provide extended storage and shelf-life characteristics compared to those outlined in MIL-PRF-85582, MIL-PRF-23377, MIL-PRF-53030, MIL-PRF-22750 and TT-P-2760.

The development of "dry" coating formulations will minimize the release of VOCs and HAPs associated with the mixing and application of wet-spray coatings and eliminate or reduce the generation of hazardous waste resulting from the disposal of partially used containers.

BACKGROUND: Solvent and waterborne coatings used in painting aerospace coating systems have volatile and hazardous components which contribute to emissions and raise environmental, safety, and health compliance concerns. Liquid paints such as polyethylenes and epoxies come as two-part mixtures. Many of these release isocyanates on mixing, have shelf-life limits, and require storage in flammable/hazardous material lockers. In addition, paint cans containing residual liquids must be disposed as hazardous waste. The currently available powder-coatings are not suitable for painting structural aluminum parts because of their high cure temperatures and they are not suitable for large exterior surfaces of systems such as aircraft because of size and temperature constraints. This Statement of Need seeks powder mixes which can be mixed with a carrier or solvent for wet-spray painting to alleviate these issues. Typical military wet-spray paint specifications, for which alternatives meeting similar performance requirements may be substituted, include MIL-PRF-85582, MIL-PRF-23377, MIL-PRF-53030, MIL-PRF-85285, MIL-PRF-22750, TT-P-2756 and TT-P-2760.

CORE STATEMENT OF NEED FOR FY 2003
POLLUTION PREVENTION – PPSON-03-04

ENVIRONMENTALLY INNOVATIVE TECHNOLOGIES FOR ELECTROPLATING AND SURFACE FINISHING: ALTERNATIVES TO NICKEL ELECTROPLATING

OBJECTIVE: The objective of this Statement of Need (SON) is to develop alternatives to nickel plating to eliminate the generation of nickel air emissions and hazardous waste in DoD industrial operations. Areas of research may involve process alternatives or materials substitution. Alternative materials suggested for conventional processes must have little or no environmental, safety or health impacts.

Proposed materials and processes must be addressed from a systems level and exhibit lower life cycle environmental impact than current processes and similar economics. DoD depot support issues (maintenance and repair) and systems' applications must be considered in the proposed effort. Baselines in materials types, quantities, costs, and environmental impact must be established and tracked during the development effort. Proposed efforts claiming environmental cost savings shall include a preliminary cost analyses focused on actual or realistic future applications and use/compliance requirements for the technology on DoD systems. The development of alternative materials or processes to supplant nickel electroplating will reduce the environmental burdens resulting from DoD air emissions and hazardous waste generated in nickel electroplating processes.

BACKGROUND: Nickel plating presents hazards in the workplace and spent materials must be treated as hazardous waste. Nickel is listed by the Environmental Protection Agency as one of the priority pollutants and is considered to be one of the 14 most noxious heavy metals. Nickel is also listed among the 25 hazardous substances thought to pose the most significant potential threat to human health at priority superfund sites. Nickel can not be destroyed in the environment - it can only be transported, change its form (oxidation state), or be sorbed to or separated from soil and/or sediment particles. Under acidic conditions, nickel is more mobile in soil and may seep into ground water.

DoD uses nickel electroplating in weapon system and aerospace component fabrication, maintenance, and repair. Responders are advised to carefully consider the relationship between the performance of proposed alternatives and the performance characteristics of specific metals and plating materials used in military system applications. Metals are generally selected for optimum fatigue life, strength-to-weight ratio, wear and corrosion resistance characteristics. Plating materials are generally selected for wear and corrosion protection characteristics, with minimum degradation of the base metal substrate. Base metal substrates are generally made of alloys of aluminum and steel. Typical aluminum alloys include ASTM 2024, 2219, 2519, 5083, and 7075. Typical steels include low-carbon alloys such as ASTM 4130, and high-strength alloys including ASTM 4340, 300M, and Aeromet 100.

Nickel coatings are used to modify or improve the surface properties such as corrosion resistance, hardness, wear and magnetic characteristics of DoD weapons and aerospace components. Nickel sulfamate plating has been widely used by the aviation community because it has beneficial physical properties over other coatings like chrome plating. One such advantage is that nickel plating can produce either a line of sight or non-line of sight deposit with compressive to zero internal residual stress; this reduces any detrimental impact on the fatigue life of the component. As a result, nickel plating is often specified to impart a favorable compressive load to the substrate and to provide good wear characteristics and hardness. Proposed alternatives should provide performance that meets or exceeds that of the current military specifications.

CORE STATEMENT OF NEED FOR FY 2003
POLLUTION PREVENTION – PPSON-03-05

ENVIRONMENTALLY BENIGN METHODS FOR THE REMOVAL OF RADAR ABSORBING MATERIAL (RAM) COATINGS

OBJECTIVE: The objective of this Statement of Need (SON) is to develop new, environmentally benign methods and/or materials for the removal of radar absorbing material (RAM) coatings from currently fielded and/or future DoD systems. Specifically, the goal is to develop materials and processes that eliminate or significantly reduce the volatile organic compounds (VOCs), hazardous air pollutants (HAPs), and hazardous waste that result from using the current class of "environmentally advantaged" chemical strippers.

The proposed research shall result in a product or process that meets or exceeds the performance of current practices. It must retain the features of low cost, portability, simplicity of use, controllability, and the extremely low potential for substrate damage possessed by hand tool processes. Impact on life cycle costs should be assessed and must be positive.

The proposed research must be addressed from a systems level perspective and must exhibit the potential for lower environmental life cycle impact than current processes. In addition, it must not degrade weapon/coating system performance. Depot and field support issues (maintenance and repair) and components/systems applications issues must be considered in the proposed effort. Baselines for the processes, materials, quantities, costs, and environmental impact must be established and tracked during the effort. The proposed technology must eliminate or significantly reduce VOCs, HAPs, and hazardous solid or liquid waste streams.

The development of an environmentally benign process for removing RAM will result in significant reductions of VOCs, HAPs, and hazardous waste streams associated with the stripping process. Worker safety will also be improved over current removal methods.

BACKGROUND: RAM coatings are an important element of stealth technology and are becoming increasingly common in DoD systems. They are currently used on aircraft such as the F-117, B-2, F-22 and the F/A-18 as well as on many surface and undersea combatant systems. They play a critical role in successfully completing many DoD missions. However, the maintenance practices associated with these RAM coatings present significant environmental as well as safety concerns.

Coating removal technologies may be classified into three broad categories, thermal, mechanical and chemical. These approaches may be used individually or in combination to ensure complete coating removal. A number of Air Force studies have been completed to evaluate the pros/cons of all three stripping methods. The Air Force is currently funding an effort for RAM removal to test the efficacy of ultra-sonic hand tools. They also plan to fund an effort to assess RAM removal using diode lasers and an effort to develop low peel strength adhesives to permit easier removal of sheet-coatings.

Traditional methods for the removal of RAM coatings from aircraft structures and components involve the use of chemical formulations. These contain strong solvating chemicals such as methylene chloride (MECL) and methyl alcohol (MA) activated with a strong organic acid or base. In most instances repeated applications of these formulations are required to remove multiple coats of paint or thick elastomeric coatings such as RAM. Scraping and/or sanding is required between applications of the strippers to remove the blistered and loosened coating. This approach involves the release of Ozone Depleting Chemicals (ODC), Volatile Organic Compounds (VOC's), Hazardous and Toxic vapors, (HAZTOX), Hazardous Air Pollutants (HAP's) as well as the production of large volumes of contaminated wastewater and solid waste.

CORE STATEMENT OF NEED FOR FY 2003
POLLUTION PREVENTION – PPSON-03-06

GREEN SYNTHESIS TECHNIQUES FOR ENERGETIC INGREDIENTS AND THEIR PRECURSORS

OBJECTIVE: The objective of this Statement of Need (SON) is to develop innovative green chemistry approaches for use as efficient, environmentally responsible techniques to produce energetic ingredients (EIs) and their precursor materials for Department of Defense applications. These include, but are not limited to, nitramines, nitroaromatics and related compounds. Areas of interest include: (1) synthesis approaches for energetic ingredients and precursor formation, nitration processes, or synthesis of nitrogen-containing polycyclic compounds; and (2) improving selectivity and efficiency in aromatic nitration reactions.

Potential research concentration areas include but are not limited to: (1) Develop approaches to C-N(NO2)- and precursor formation, nitration, or the synthesis of nitrogen-containing polycyclic rings; (2) Develop approaches towards selective and efficient nitration of aromatic ring systems; (3) Develop and use predictive tools to optimize these new techniques; (4) Assemble heterologous pathways in conjunction with the above for coordinated and combinatorial diversification of precursors in EI synthesis; and (5) Use theoretical and biochemical principles to enable hybrid processing schemes.

Estimates suggest that waste streams associated with the production of energetic materials can be substantially reduced relative to conventional commercial processes. Improved environmentally responsible syntheses of energetic ingredients or selective nitration techniques will substantially reduce source amounts of hazardous wastes and undesirable isomer by-products through the elimination of high VOC solvents, heavy metal catalysts, and toxic chemicals used by the current classical, highly polluting and inefficient chemical routes. In addition, because of the high efficiency and selectivity of conversions, product yields are expected to be higher than those of the conventional processes. Innovative synthetic routes are important from an environmental perspective since they are typically run under mild reaction conditions (energy savings); selectively produce products (cleaner products); avoid the use of heavy metal catalysts; virtually eliminate undesirable isomers and by-products with their attendant treatment needs, produce little or no hazardous wastes, and frequently provide near theoretical product yields.

BACKGROUND: Green Chemistry has been touted as the logical alternative to traditional "pollute then clean-up" strategies. The U. S. EPA and National Science Foundation NSF established a green chemistry program in 1991 entitled "Technology for a Sustainable Environment". In recent years, the American Chemical Society has sponsored seminars and program sessions at their national meetings on the topic of green chemistry. The use of these technologies has been largely unexplored as a method to synthesize energetics and their precursors. From an environmental perspective, these alternate synthesis approaches offer environmental advantages over conventional chemical catalysts because they are typically environmentally benign, biodegradable, and resource efficient. Major industrial processes already exist for fine and commodity chemical syntheses using these methods.

Currently the construction of suitable cyclic, polycyclic, heterocyclic, and caged C-N(X)-C precursors (where X = nitroso, acetyl, or benzyl) and the subsequent introduction of the nitro functional group is fraught with the common limitations of organic chemistry. Strategies that include the incorporation of polyaza- moieties introduce still further synthetic complexities. Despite decades of research, the production of EIs still relies on a limited number of classical nitration/nitrolysis chemical reactions. These reactions often employ harsh and non-selective reaction conditions. Consequently, the costs for producing EIs increases due to protection/deprotection procedures and waste disposal issues.

CORE STATEMENT OF NEED FOR FY 2003
POLLUTION PREVENTION – PPSON-03-07

ENVIRONMENTALLY ACCEPTABLE STAB DETONATORS FOR MEDIUM CALIBER MUNITIONS

OBJECTIVE: The objective of this Statement of Need (SON) is to develop new, small, impact initiated devices (IID's) for DoD medium caliber munitions that are environmentally benign compared to the current designs. The existing detonators contain hazardous compounds including lead styphnate, lead azide, tetracene, and barium nitrate and, depending upon the individual detonator type, either antimony sulfide or antimony trisulfide. The new IID's shall be designed such that the output from the device will cause a lead or main explosive charge to detonate. The small IID's are to be sized such that they will be compatible with the current fuzes being produced for medium caliber (20-60mm) ammunition and have sufficient output energy to initiate lead and main charges containing the current explosives and to initiate explosives that are militarily classified as "insensitive". In addition, the new IID's must ultimately provide the same relative level of affordability ($0.90 to $1.50 each in production quantities) as the current designs. The development of environmentally benign, small IID's will result in significant reductions in the release of and exposure to hazardous materials during manufacture, operational use and demilitarization of medium caliber fuzes.

BACKGROUND: Current medium caliber high explosive projectiles are activated at the target by the rapid forcing of a firing pin into the sensitive end of an impact sensitive (stab) detonator. The detonator materials rapidly decompose generating a pressure/shock force that is transferred to either a lead or main explosive charge. The transferred force is sufficient in magnitude and duration that it causes the receptor explosive charge to detonate, rupturing the projectile and, if included in the design, forming an armor piercing shaped charge jet.

The initiating (sensitive) mix in all current medium caliber detonators is composed of lead styphnate, lead azide, tetracene, and barium nitrate. Depending upon the individual detonator type, either antimony sulfide or antimony trisulfide is also included in the initiating mix. All of the detonators then have an additional charge of lead azide placed behind the initiating mix that outputs to a booster charge of RDX. All of these compounds that comprise the initiating mix contain heavy metals which are either mild toxins or produce toxins when they rapidly decompose. Although highly effective, the heavy metals such as barium, antimony, and lead that are used in these initiating mix compositions have been identified as hazardous materials per EPA regulation 10 CFR, part 1910 and therefore should be eliminated and replaced. Based upon current production quantities for the next 5 years, approximately 2500 pounds of lead compounds, tetracene, barium nitrate and antimony compounds will be assembled into these detonators. This does not include the waste material generated in the manufacture of the basic chemical ingredients.

The physical volume available in the munition for the detonator is a major design constraint in all of the medium caliber rounds. The detonators in this family of fuzes range in size from 0.0855 to 0.147 inches in diameter and 0.143 to 0.266 inches in length. Despite their small size, these devices are required to perform rapidly and reliably using only the kinetic energy available from the impact of the projectile with an object. Impact energy sensitivity is measured by dropping a 0.25 ± 0.01 ounce weight onto a firing pin positioned above the detonator. Depending upon the specific detonator, this drop height varies from 3 to 5 inches. Each detonator also has an output requirement measured by a specified dent in a lead (witness) plate. The specifics of the dent can be found in the applicable specifications, MIL-D-50865, MIL-D-14978 or MIL-D-70436. Failure to reliably initiate will result in the creation of an unexploded ordnance hazard.

CORE STATEMENT OF NEED FOR FY 2003
POLLUTION PREVENTION – PPSON-03-08

ENVIRONMENTALLY ACCEPTABLE PROPELLANT COMPOSITIONS FOR MEDIUM CALIBER AMMUNITION

OBJECTIVE: The objective of this Statement of Need (SON) is to reduce or eliminate environmentally unfriendly materials used in the formulation and manufacture of gun propellants for military ammunition with the intent of early transition to medium caliber (20mm to 60mm) ammunition. Specifically, the goal is to identify suitable alternatives for diphenylamine and barium nitrate in these formulations. The resulting propellant shall provide equivalent or increased level of performance compared to the current formulations.

The development of environmentally benign propellants will result in the significant reduction and release of hazardous materials during manufacture, use, and demilitarization of medium caliber ammunition.

BACKGROUND: Gun propellants are highly energetic mixtures which, when ignited, produce large quantities of gaseous products and an enormous amount of heat. The complete combustion or deflagration of the propellant occurs in milliseconds. The hot gases released in a confined space during combustion generate pressure that is transformed into the work of projectile motion. The main energetic component of military gun propellants is nitrocellulose (NC). Where a more energetic propellant is required, NC may be impregnated with nitroglycerine (NG). In addition to this basic formulation, most military gun propellants also require a coating of deterrent plasticizer for burn rate control, and a surface application of inorganic compounds that serve as ignition aids or provide flash reduction. Stabilizing additives are also added to prolong propellant shelf life.

Diphenylamine (DPA), a suspected carcinogen, acts as a stabilizer in the propellant to prevent the deterioration of the nitrocellulose. Barium nitrate, a heavy metal and also a hazardous material, is used in some medium caliber propellants as an oxidizing agent to make the propellant more readily ignitable.

Barium nitrate is a moderately poisonous material that can irritate the mucous membranes and the skin producing dermatitis and eye, nose, and ear irritation. When heated, the toxic fumes may produce gastrointestinal irritation. DPA is a known toxin and a suspected carcinogen. Safe disposal of excess or expired propellant is difficult because of the sensitive, explosive, and toxic nature of these materials. Over the next 5 years, approximately 7,700 pounds per year of DPA and 2000 pounds per year of barium nitrate will be incorporated into medium caliber munitions.

SEED STATEMENT OF NEED FOR FY 2003
POLLUTION PREVENTION – PPSEED-03-01

ENVIRONMENTALLY ACCEPTABLE ALTERNATIVES FOR LITHIUM RESERVE BATTERIES FOR MEDIUM CALIBER MUNITIONS

OBJECTIVE: The objective of this Statement of Need (SON) is to develop environmentally benign power supplies for future medium caliber ammunition applications. The application requires that the power supplies operate in a severe gunfire environment (extremely high linear acceleration [100+K G's] and spin rates [1000 - 1800 rev per sec]), have a storage life greater than twenty years, and be fully active within milliseconds of shot start. These power supplies are to be sized such that they will be compatible (volume, weight, energy, and power) with the newest electronic fuzes being developed for medium caliber (20-60 mm) ammunition. A typical design space allocation for this type of power supply is approximately 18mm in diameter and 12.5mm in length. The power supply will be expected to provide a minimum of 4 volts with a current drain of between 20 and 200 milliamps for up to tens of seconds, depending upon the circuit design plus the number and types of sensors onboard the fuze. In addition, these power supplies must ultimately provide the same relative level of affordability as current designs (depending on quantity produced, $3 to $30 each).

BACKGROUND: The power supplies being considered for use in electronic fuzes in current medium-caliber gunfire applications are primarily lithium-based chemical batteries. The most common chemistry found in these batteries uses metallic lithium as the cathode and thionyl chloride as the electrolyte. A less-widely used chemistry uses sulfuryl chloride as the electrolyte. All of these active materials are environmentally unacceptable. Lithium metal is moderately toxic. In addition, it reacts violently with water and can cause burns if touched. Reacting with water, it releases hydrogen, which may ignite. Thionyl chloride is a very caustic material with vapors that are a breathing hazard. Sulfuryl chloride is an even more caustic material that eats through anything but glass, Teflon, and nickel. Based upon projected production quantities for these batteries in new medium caliber rounds, greater than 2300 pounds of lithium will be required to meet the production build.

SEED STATEMENT OF NEED FOR FY 2003
POLLUTION PREVENTION – PPSEED-03-02

ENVIRONMENTALLY ACCEPTABLE ALTERNATIVES FOR CHROMATED SHIELDED METAL ARC WELDING RODS

OBJECTIVE: The objective of this Statement of Need (SON) is to develop non-chromated Shielded Metal Arc Welding (SMAW) electrodes to replace the existing chromated electrodes which are used to weld stainless steel. Specifically, the proposed effort shall identify and demonstrate the feasibility of concepts to fabricate chromium-free electrodes for these applications. Ultimately, these electrodes will be expected to meet or exceed the performance of the current classes of electrodes while reducing the levels of hazardous air pollutants and toxic emissions.

BACKGROUND: Four Navy shipyards, four Army Depots, two Army Arsenals, and four Air Force Depots list welding as one of their major capabilities. These organizations conduct a significant amount of welding on DoD weapons systems and components. The Navy shipyards alone consume approximately 18,000 pounds of chromium in welding rods per year. Gas tungsten-arc, plasma-arc, gas metal-arc, shielded metal-arc and submerged-arc welding are used extensively for joining stainless steel. Of these, shielded metal-arc welding, or "stick" welding, is the most versatile for work to be done in the field or in drafty areas because less equipment is required and because, under adverse conditions, the shielding obtained from decomposition of the electrode covering during welding is more dependable than gas shielding.

Shielded metal-arc welding is a manual arc welding process in which the heat for welding is generated by an electric arc established between a flux-covered consumable electrode and the work. The electrode tip, weld puddle, arc, and adjacent areas of the workpiece are protected from atmospheric contamination by a gaseous shield obtained from combustion and decomposition of the flux covering. Additional shielding is provided for the molten metal in the weld puddle by a covering of molten flux (slag). Filler metal is supplied by the core of the consumable electrode and, with certain composite electrodes, from metal powder mixed with the electrode covering.

While the shielded metal-arc welding process is convenient and dependable, it also generates large quantities of fumes and air emissions. Because chromium is a major constituent in stainless steel alloys and the welding rods contain from 11% to 22% chromium, there is also high chromium content in the fumes. In recent years, as much as 200 pounds per year of chromium fumes were generated at a single site conducting welding repairs on aircraft carriers. It has been suggested that as much as 95% of the welding fumes originate from the melting of the electrode or wire consumable filler material.

Welding fumes and gases cannot be classified simply. The composition and quantity of both are dependent upon the metal being welded, the process, procedures, and electrodes used. Other conditions which also influence the composition and quantity of the fumes and gasses to which workers may be exposed include: coatings on the metal being welded, the number of welders and the volume of the work area, the quality and amount of ventilation, the position of the welder's head with respect to the fume plume, as well as the presence of contaminants in the atmosphere (such as chlorinated hydrocarbon vapors from cleaning and degreasing activities). When the electrode is consumed, the fume and gas decomposition products generated are different in percent and form from the base ingredients in the electrode. The exposure level for welding fume has been established at 5 mg/m^3 with the Occupational Safety and Health Administration's (OSHA) PEL and the American Conference of Governmental Industrial Hygienists' (ACGIH) threshold limit value (TLV).

SUPPLEMENTAL STATEMENT OF NEED FOR FY 2002
UNEXPLODED ORDNANCE – UXSON-02-03

ADVANCED APPROACHES TO UNEXPLODED ORDNANCE (UXO) DETECTION, DISCRIMINATION, AND REMEDIATION

OBJECTIVE: The overall goal of this Statement of Need (SON) is to develop technologies that will provide new solutions to the diverse problems of UXO-contaminated land sites. Work under this SON may be to develop new sensors, platform improvements (including hand-held, man-portable, vehicular and airborne), discrimination techniques, signal processing/data analysis techniques, removal technologies, or to improve technologies that support such efforts through navigation, geo-location or hazard assessments. Advances are needed in all aspects of the procedures for the detection, discrimination and remediation of UXO. Capabilities are needed for a wide variety of terrain and vegetation and at sites whose ordnance distribution and extent of clutter can be radically different. Geologic variability across the country is significant and can also impact performance. Many sites or sections of sites have sparsely distributed subsurface ordnance and clutter items that can clearly be separated, while other areas have almost a continuously overlap of suspected items which need to be assessed. Items ranging from 20-mm shells to 2000-lb bombs must be detected and discriminated from other non-hazardous items in the subsurface.

Within this overarching goal, the research and development proposed under this SON should provide innovative advancements that support achievement of any of these five UXO technology objectives (not in any priority order): (1) Wide Area Assessment, (2) Production Ground Surveys, (3) Cued Identification, (4) Removal and Disposal, and (5) Hazard Assessment.

Results from the technologies developed under this SON will provide new capabilities for use under the Department's UXO remediation strategy. These technologies will aid in achieving the principal goal of the UXO remediation technology development effort, which is to produce more effective and efficient processes and procedures for reliable and cost-effective response to UXO at current and former DoD sites. Benefits include significant cost savings, significant increases in probability of detection, significant reduction in false-alarms, and increased capabilities to deploy advanced technologies for a wide diversity of site conditions.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for Base Realignment and Closure (BRAC), at Formerly Used Defense Sites (FUDS) and other closed ranges. The detection and remediation of UXO at closed, transferred and transferring (CTT) ranges, munitions burning and open detonation areas, and burial pits is the one of the DoD's most pressing environmental problems. The UXO characterization and remediation activities conducted at DoD sites using currently available technology is extremely expensive and often yields unsatisfactory results, due mainly to the inability of current technology to detect all UXO that may be present at a site and the inability to discriminate between UXO and non-hazardous items. Field experience indicates that often in excess of 90% of objects excavated in the course of a UXO remediation are found to be non-hazardous items (false alarms). As a result, most of the costs to remediate a UXO site are currently spent on excavating these false targets.

The UXO remediation technology program seeks to both maximize the probability of detection and minimize the false alarm rate. Our goal is to meet the highest probability of detection desired (near 100%) at each site while reducing the false alarm rate by up to a factor of a 100 for highly cluttered sites. These two metrics are closely coupled and must be tackled jointly. In all our technology objectives the DoD UXO RDT&E program is striving to provide tools and full visibility to site managers, regulators and communities concerning the expected performance and associated cost and impact for any cleanup decision.

SUPPLEMENTAL STATEMENT OF NEED FOR FY 2002
UNEXPLODED ORDNANCE – UXSON-02-04

UNEXPLODED ORDNANCE (UXO) SITE CHARACTERIZATION AND REMEDIATION TECHNOLOGIES FOR UNDERWATER SITES

OBJECTIVE: The objective of this SON is to develop technologies to support characterization and/or clearance actions for unexploded ordnance found on underwater sites. Research and development proposals should focus on one or more of the following activities: (1) novel engineering-based techniques/platforms that overcome the access limitations for locating UXO present in underwater locations (e.g. coastal areas, marine sediments, harbors, estuaries, lakes, ponds and wetlands); (2) improved signal processing and or sensors to aid in discrimination of debris/clutter from targets in underwater UXO-contaminated areas; or (3) mechanical or other methods to aid in the cost effective and safe direct clearance of underwater UXO-contaminated sites; these may include render-safe technologies.

Modern geophysical surveying techniques can effectively be used to characterize sites potentially contaminated with UXO on dry land. For easily accessible sites where signatures are sparse and anomalies are spatially isolated, these tools can guide detection-driven remediation activities and in some cases can effectively screen clutter from ordnance. However, many sites contain UXO underwater, where environmental/physical conditions restrict established effective characterization and remediation alternatives. To appropriately direct remediation efforts and to reliably clean these underwater UXO areas, SERDP intends to develop techniques that provide reliable target detection and discrimination, and remediation tools that can cost effectively and safely remove or render-safe any encountered UXO. These remediation tools may prescribe what combination of detection-driven approaches and mechanical or other removal actions should be used. Results from this work will provide a new capability to cost effectively characterize and remediate underwater UXO sites resulting in a significant cost savings.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for base realignment and closure (BRAC) and at Formerly Used Defense Sites (FUDS). Particularly difficult is the characterization and remediation of those sites that have large numbers of underwater UXO present in former target and training areas, as well as from other military-related activities. Presently, there exists: (1) no effective capability to survey these underwater areas and map the location of all UXO for site characterization and remediation; and, (2) some render-safe techniques that could be improved. Factors such as small target size, target burial, shallow water, environmental noise (as from surface waves and reverberation), and water turbidity all reduce sensor performance during site characterization - while the mere submerged nature of the UXO restricts access during site clearance.

Many active and former military installations have ordnance ranges and training areas that include adjacent water environments such as ponds, lakes, rivers, estuaries, and coastal ocean areas. Wartime activities, dumping, and accidents have also generated significant unexploded ordnance (UXO) contamination in the coastal and inland waters here in the United States and abroad. The problem of underwater UXO contamination has commanded more attention with island and coastal nations overseas than in the United States for a number of reasons. First, their ratio of underwater land area under economic control to surface land area is higher, so the sea floor represents a proportionally greater resource. Next, much wartime activity was directed at stopping sea commerce; consequently, significant UXO contamination is located in important areas such as harbors and channels. Finally, marine technology has advanced to allow access to deeper waters. On the other hand, much of the U.S. underwater contamination has occurred near military practice and test ranges which tend to be remotely located, so that there has been minimal direct economic impact. Thus clean up efforts at FUDS sites have typically ended at the water’s edge. But what started out as a remote site 50 years ago, is often no longer the case. The issue of underwater UXO contamination is an increasing public concern.

SEED STATEMENT OF NEED FOR FY 2003
UNEXPLODED ORDNANCE – UXSEED-03-01

INNOVATIVE APPROACHES TO UNEXPLODED ORDNANCE (UXO) CLEANUP

OBJECTIVE: The overall goal of this Statement of Need (SON) is to develop proof of principle for new sensors, explore new discrimination techniques, illustrate new removal or disposal technologies, or to explore technologies that support such efforts through improvements in navigation, geo-location or ground, water, or aerial vehicle technologies. Advances are needed in all aspects of the detection, discrimination and disposal of UXO in both land and water environments. Items ranging from 20-mm shells to 2000-lb bombs must be detected and discriminated from other non-hazardous items in a variety of environments, using a variety of supporting vehicle and navigation technologies. Algorithms are needed that can exploit data from current state-of-the-art sensors and advanced sensors that are now becoming available. Once hazardous and non-hazardous items are distinguished, the hazardous items must be removed and/or disposed of in a cost-effective manner. The proposed work should, if successful, lead to a continued development effort, which ultimately could result in the fielding of new sensors, implementation of algorithms, testing of removal or disposal techniques, or in improving operation of the approaches used to date though improved navigation, geo-location or vehicle performance. There is interest in any aspect of improving UXO clean-up procedures in both land and water environments.

BACKGROUND: As a result of past military training and weapons testing activities, UXO is present at sites designated for base realignment and closure (BRAC) and a formerly used defense sites (FUDS) in both land and water environments. Using current technologies, the cost of identifying and disposing of UXO in the United States is estimated to be in the billions of dollars. In the land environment, current technology has shown the ability to detect individual sub-surface UXO, but not to reliably discriminate UXO from other items that pose no risk. Thus, typical survey methods currently employed require an exhaustive search of contaminated areas, have an excessive level of false alarms, and lead to expensive removal and disposal procedures with potentially adverse environmental impacts. Presently, there exists no effective capability to survey underwater areas and map the location of all UXO for site characterization and remediation. Removal and disposal techniques for underwater UXO could be improved.

APPENDIX G
List of Acronyms

AAR	Annular After Reactor
AATDF	Advanced Applied Technology Demonstration Facility
AB	After Burner
ACGIH	American Conference of Governmental Industrial Hygienists
AEMSS	Advanced Enclosed Mast/Sensor System
AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
AFP	Amplifying Fluorescent Polymer
AFRL	Air Force Research Laboratory
AFSM	Alternative Future Scenario Modeling
ALGLE	Aging Landing Gear Life Extension
ANAD	Anniston Army Depot
AP	Ammonium Perchlorate
APG	Aberdeen Proving Ground
APGEMS	Air Pollutant Graphical Environmental Modeling System
ARL	Army Research Laboratory
As	Arsenic
ATOFMS	Aerosol Time of Flight Mass Spectrometer
ATTACC	Army Training and Testing Area Carrying Capacity
BA	biological assessment
BAA	Broad Agency Announcement
BCVI	Black-Capped Vireo
BO	biological opinion
BOOM-SAR	Boom Synthetic Aperture Radar
BP	Blossom Point
BRAC	Base Realignment and Closure
CA	Coupling Agent
CAAA	Clean Air Act Amendments
CAH	Chlorinated Aliphatic Hydrocarbon
CARB	California Air Resources Board
CARC	Chemical Agent Resistant Coating
CAV	Composite Armored Vehicle
CBP	Constant Breech Pressure
CCAD	Corpus Christi Army Depot
CCC	Chromate Conversion Coating
Cd	Cadmium
cDCE	cis-1,2-dichloroethene
CE	Capillary Electrophoresis
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFD	Computational Fluid Dynamics
CFE	Cape Fear estuary
CMS	Cylindrical Magnetron Sputtering
CNC	Condensation Nucleus Counter

CO	Carbon Monoxide
CP	Conductive Polymer
Cr	Chromium
CRREL	Cold Regions Research and Engineering Laboratory
CRTF	Coral Reef Task Force
CT	Carbon Tetrachloride
CTT	Closed, Transferred and Transferring
Cu	Copper
CuCC	Cu complexation capacity
CWA	Clean Water Act
CWT	Continuous Wavelet Transform
DARPA	Defense Advanced Research Projects Agency
DC	Direct Current
DCE	Dichloroethene
DDR&E	Director, Defense Research and Engineering
DEQ	Department of Environmental Quality
DETRS	DoD Environmental Technology Requirements Strategy
DGGE	Denaturing Gradient Gel Electrophoresis
DHR	Directional Hemispherical Reflectance
DIRB	Dissimilatory Iron-Reducing Bacteria
DNAPL	Dense Non-Aqueous Phase Liquid
DNT	Dinitrotoluene
DoD	Department of Defense
DODEC	DoD Regional Environmental Colloquium
DOE	Department of Energy
DPA	Diphenylamine
DPV	Diver Propulsion Vehicle
DSB	Defense Science Board
DTAP	Defense Technology Area Plan
DTIC	Defense Technical Information Center
DTO	Defense Technology Objective
DUSD(I&E)	Deputy Under Secretary of Defense for Installations and Environment
DWT	Discrete Wavelet Transform
EAE	Environmentally Acceptable Endpoint
EAM	Effective Area Model
ECMI	Ecosystem Characterization and Monitoring Initiative
ECRS	Experiment Controlled Release System
EDYS	Ecological Dynamics Simulation
EED	electro-explosive device
EK	electrokinetics
EM	Electromagnetic
EMI	Electromagnetic Induction
EMSP	Environmental Management Science Program
EO	Executive Order
EOD	Explosive Ordinance Disposal
EPA	Environmental Protection Agency
ERDC	Engineer Research and Development Center
ESA	Endangered Species Act
ESD	Electro-Spark Deposition
ESF	Event Severity Factor

ESOH	Environmental, Safety, and Occupational Health
ESR	Enhanced Source Removal
ESTCP	Environmental Security Technology Certification Program
EWG	Executive Working Group
FDP	Fluorescent Dye Penetrant
Fe	Iron
FHASM	Fort Hood Avian Simulator Model
FIB	Focused Ion Beam
FISH	Fluorescent In-situ Hybridization
FP	Fluorescent Penetrant
FR	Fouling Release
FRTR	Federal Remediation Technologies Roundtable
FTIR	Fouier Transform Infrared Reflectance
FTMA	Future Tank Main Armament
FUDS	Formerly Used Defense Sites
GCWA	Golden-Cheeked Warbler
GIS	Geographic Information System
GPR	Ground-Penetrating Radar
GRFL	Groundwater Remediation Field Laboratory
H_2	Hydrogen
HAP	Hazardous Air Pollutant
HAZTOX	Hazardous and Toxic vapors
HCAT	Hard Chrome Alternatives Team
HCI	Hydrogen Chloride
HE	High Explosive
HFBA	Hierarchical Foreground Background Analysis
Hg	Mercury
HMX	Octahydro-1,3,5,7-Tetranitro 1,3,5,7-Tetrazocine
HOC	hydrophobic organic compound
HQDA	Headquarters, Department of Army
HSI	Hyperspectral Imaging
HVOF	High-Velocity Oxygen Fuel
I&E	Installations and the Environment
ID	Internal Diameter
IDLAMS	Integrated Dynamic Landscape Analysis and Modeling System
IER	Ion-exchange Resin
IID	impact initiated device
IMS	ion mobility spectrometry
IP	Intellectual Property
IPR	In-Progress Review
IPSC	Interagency Perchlorate Steering Committee
ISCO	In Situ Chemical Oxidation
ITAM	Integrated Training Area Management

JASPPA	Joint Acquisition and Sustainment Pollution Prevention Activity
JEMP	Joint Engineers Management Panel
JETC	Jet Engine Test Cell
JG-PP	Joint Group on Pollution Prevention
JSF	Joint Strike Fighter
LANDSAT	Land Remote-Sensing Satellite
LB	Luria-Bertain
LCF	Local Condition Factor
LDH	layered double hydroxide
LHAAP	Longhorn Army Ammunition Plant
LM	Liquid Molding
LMS	Land Management System
LO	Low Observable
μECD	micro-electron capture detection
MA	Mechanical Alloying
MA	Methyl Alcohol
MALDI-MS	Matrix Assisted Laser Desorption Ionization Mass Spectrometry
MARPOL	International Maritime Organizations Marine Pollution Convention
MCAGCC	Marine Corps Air-Ground Combat Center
MECL	Methylene Chloride
MEK	Methyl Ethyl Ketone
MF-EMI	Medium Frequency Electromagnetic Induction
MIC	Metastable Intermolecular Composites
MIP	Membrane Interface Probe
MIT	Massachusetts Institute of Technology
MLFMA	Multi-Level Fast-Multipole Algorithm
MNA	monitored natural attenuation
MPN	Most Probable Number
MRE	Meal Ready-to-Eat
MSAT	Mobile Source Air Toxics
MSS	Multispectral Scanner
MTADS	Multi-Sensor Towed Array Detector System
MTBE	Methyl Tert-Butyl Ether
MURI	Multi University Research Initiative
NAAQS	National Ambient Air Quality Standard
NADEP	Naval Aviation Depot
NAPL	Non-Aqueous Phase Liquid
NAS	Naval Air Station
NASA	National Aeronautics and Space Administration
NBVC	Naval Base Ventura County
NC	Nitrocellulose
NCIBRD	National Center for Integrated Bioremediation Research and Development
NCMS	National Center for Manufacturing Sciences
NDCEE	National Defense Center for Environmental Excellence
NDI	Nondestructive Inspection
NEETC	National Environmental Education and Training Center
NETTS	National Environmental Technology Test Site
NFESC	Naval Facilities Engineering Services Center
NG	Nitroguanidine

NGP	Next Generation Fire Suppression Technology Program
Ni	Nickel
NIST	National Institute of Standards and Technology
NOAA	National Oceanic and Atmospheric Administration
NOD	natural oxidant demand
NOx	Nitrogen Oxide
NRL	Naval Research Laboratory
NSWC	Naval Surface Warfare Center
NSWCCD	Naval Surface Warfare Center Carderock Division
NTL	National Test Location
NV-LOC	No-VOC Low Observable Coating
O&M	Operation and Maintenance
OAP	Oligoaniline Acrylate Polymer
OB/OD	Open Burning/Open Detonation
OC	organic carbon
ODC	Ozone Depleting Chemical
ODS	Ozone Depleting Substance
ODUSD(ES)	Office of the Deputy Under Secretary of Defense for Environmental Security
ONR	Office of Naval Research
OPC	Optical Particle Counters
ORD	Office of Research and Development
OSH	Occupational Safety and Health
OSHA	Occupational Safety and Health Administration
OWS	Oil/Water Separator
PAC	Project Advisory Council
PAH	Polycyclic Aromatic Hydrocarbon
PAS	Photoelectric Aerosol Sampler
Pb	Lead
PCB	Polychlorinated Biphenyls
PCDD/F	polychlorinated dibenzo-p-dioxins and dibenzofurans
PCE	Perchloroethylene
PCR	Polymerase Chain Reaction
PDM	Programmed Depot Maintenance
PE-ECD	Photoemissive Electron Capture Detector
PE-IMS	Photoemissive Ion Mobility Spectrometer
PED	Photoacoustic Elemental Device
PEL	Permissible Exposure Limit
PETN	pentaerythytol tetranitrate
PI	Principal Investigator
PLFA	Phospholipid Fatty Acids Analysis
PM	Particulate Matter
PMC	Polymer-Matrix Composite
PNNL	Pacific Northwest National Laboratory
PRB	Permeable Reactive Barrier
PTFE	Polytetrafluoroethylene
QA/QC	Quality Assurance/Quality Control
QSAR	Quantitative Structural Activation Reaction

R&D	Research and Development
RABITT	Reductive Anaerobic Biological In-Situ Treatment Technology
RAM	Radar Absorbing Material
RCRA	Resource Conservation and Recovery Act
RCW	Red-Cockaded Woodpecker
RDT&E	Research, Development Test & Evaluation
RDX	Hexahydro-1,3,5-trinitro-1,3,5-triazine
RF	Radio Frequency
RFLP	Restriction Fragment Length Polymorphisms
ROV	Remotely Operated Vehicle
RP	Red Phosphorus
RPI	Rensselaer Polytechnic Institute
RSL	Remote Sensing Lab
RTDF	Remediation Technologies Development Forum
RTV	Room Temperature Vulcanizing
RUSLE	Revised Universal Soil Loss Equation
S&T	Science and Technology
SAB	Scientific Advisory Board
SABC	Surface-Active Block Copolymer
SALSA	Semi-Arid Land Surface Atmosphere
SAR	Synthetic Aperture Radar
SBR	Sequential Batch Reactor
SCAPS	Site Characterization and Analysis Penetrometer System
SCM	Source Characterization Model
SCORE	Southern California Off-Shore Range
SDSS	Spatial Decision Support System
SEBS	Styrene-Ethylene/Butylene-Styrene
SEMP	SERDP Ecosystem Management Program
SERDP	Strategic Environmental Research and Development Program
SERS	Surface Enhanced Raman Sensor
SH-SAW	Shear-Horizontal Surface Acoustic Wave
SHS	Self-Propagating, High-Temperature Synthesis
SI	Sequential Injection
SIU	Southern Illinois University
SMAW	Shielded Metal Arc Welding
SNL	Sandia National Laboratory
SOC	Surface Optics Corporation
SODS	Seismic Ordnance Detection System
SON	Statement Of Need
SOx	sulfur oxides
SPE	solid-phase extraction
SPGG	solid-propellant-generated gases
SPH	Self-Propelled Howitzer
SVE	Soil Vapor Extraction
SVET	Scanning Vibrating Electrode Technique
SWIR	Short Wave Infrared
1,2,3,4-TCDD	1,2,3,4-tetrachlorodibenzo-p-dioxin
TAC	Technical Advisory Committee
TCA	Trichloroethane
TCE	Trichloroethylene

TCu	total copper
TD	Total Dissolved
TDR	Time Domain Reflectometry
TES	Threatened or Endangered Species
TLM	Test Location Manager
TLV	Threshold Limit Value
TNT	Trinitrotoluene
TRI	Toxic Release Inventory
TSE	Twin Screw Extruder
TTAWG	Technology Thrust Area Working Group
TVC	Trapped Vortex Combustor
UAT	Urban Air Toxic
UNDS	Uniform National Discharge Standards
UNR	University of Nevada-Reno
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USGS	U.S. Geological Survey
UV	ultraviolet
UWB	Ultra Wide Band
UXO	Unexploded Ordnance
VARTM	Vacuum-Assisted Resin Transfer Molding
VC	Vinyl Chloride
VCC	Vortex Containment Combustion
VCPI	Visual Cleaning Performance Indicator
VOC	Volatile Organic Compound
VSF	Vehicle Severity Factor
WASI	Wide-Area Spectral Imaging
WES	Waterways Experiment Station
WHOI	Woods Hole Oceanographic Institution
WIPT	Working Level Integrated Product Team
WQC	water quality criterion
XAS	X-ray Absorption Spectroscopy
XSD	Halogen Specific Detector
Zn	Zinc

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